BASAL TURONIAN AMMONITES FROM WEST TEXAS

by W. J. KENNEDY, C. W. WRIGHT *and* J. M. HANCOCK

ABSTRACT. A rich ammonite fauna is described from the basal Turonian *Pseudaspidoceras flexuosum* Zone of west Texas. Taxa present include typically Boreal, Tethyan, and US Western Interior species and widely occurring forms of the bivalve *Mytiloides*. This co-occurrence of key species from different faunal realms and provinces provides a basis for correlation of the base of the Turonian stage. Species present are the ammonites *Quitmaniceras reaseri* Powell, 1963, *Kamerunoceras calvertense* Powell, 1963, *Pseudaspidoceras flexuosum* Powell, 1963, *Mammites powelli* sp. nov., *Vascoceras proprium* Reyment, 1954, *Fagesia catinus* (Mantell, 1822), *Neoptychites* sp., *Wrightoceras munieri* (Pervinquière, 1907), *Thomasites adkinsi* (Kummel and Decker, 1954), *Allocrioceras dentonense* Moreman, 1942, *A. larvatum* (Conrad, 1855), *Sciponoceras* sp., and *Worthoceras* cf. *vermiculus* (Shumard, 1860). The *Mytiloides* present is referred to *M. columbianus* (Heinz, 1935), the *M. opalensis* of authors (*non* Böse, 1923).

ELUCIDATION of the faunal succession across the Cenomanian–Turonian boundary and inter-regional correlation around the level of this boundary are among the more intransigent problems of mid-Cretaceous biostratigraphy. The reasons for this are: (i) marked provincialism of ammonite faunas at this time, with Tethyan ammonite faunas dominated by vascoceratids and Boreal ones characterized by mammitids and euomphaloceratids, and only limited geographical intermingling of key taxa; (ii) sequences in the classic areas of western Europe are attenuated and interrupted by minor non-sequences, while many areas of the world are characterized, at this level, by condensed, atypical facies and reduced diversity faunas of many groups as a result of an important oceanic anoxic event (Schlanger *et al. in press*). It is, for instance, obvious that marked faunal turnover at this stage boundary in the US Western Interior (Kauffman 1970, fig. 6), discussed at some length by Kauffman *et al.* (1978, p. XXIII.13) is a result of both environmental and biogeographic complexities.

Hancock and Kennedy (1981) reviewed the indirect evidence for the view that the Lower Turonian of Tethys was actually equivalent to the Upper Cenomanian of Boreal regions, while Hook and Cobban (1981), Wright and Kennedy (1981), Amard *et al.* (1983), and Bengtson (1983) recorded associations of Boreal Upper Cenomanian and Tethyan Lower Turonian ammonites, but only with the description of the co-occurrence of *Metoicoceras geslinianum* (d'Orbigny, 1850) and *Vascoceras cauvini* Chudeau, 1909 in Israel (Lewy *et al.* 1984) has a precise link between these faunas been documented. Because of these problems the Cenomanian–Turonian boundary has been drawn at several different levels on the basis of different macrofossil and microfossil groups (see discussion in Wright and Kennedy 1981; Birkelund *et al.* 1984; Kennedy, 1984, 1985). A number of workers have recently proposed that the most acceptable macrofossil indicator for the base of the Turonian is the appearance in quantity of the inoceramid bivalve *Mytiloides* Brongniart, 1822. In particular, the appearance of the species *M. opalensis* (Böse, 1923) has been taken as a basal Turonian marker (e.g. Seitz 1952, 1956; Tröger 1967, 1978, 1981; Seibertz 1979; Kauffman *et al.* 1978 and references therein). It is, therefore, somewhat unfortunate that *M. opalensis* (Böse, 1923) is a younger Turonian species. The basal Turonian '*M. opalensis*' of authors is, following the unpublished work of Dr W. A. Cobban, *M. columbianus* (Heinz, 1935). It occurs in abundance in west Texas, where it is associated with a rich ammonite assemblage described below.

[Palaeontology, Vol. 30, Part 1, 1987 pp. 27–74, pls. 1–10.]

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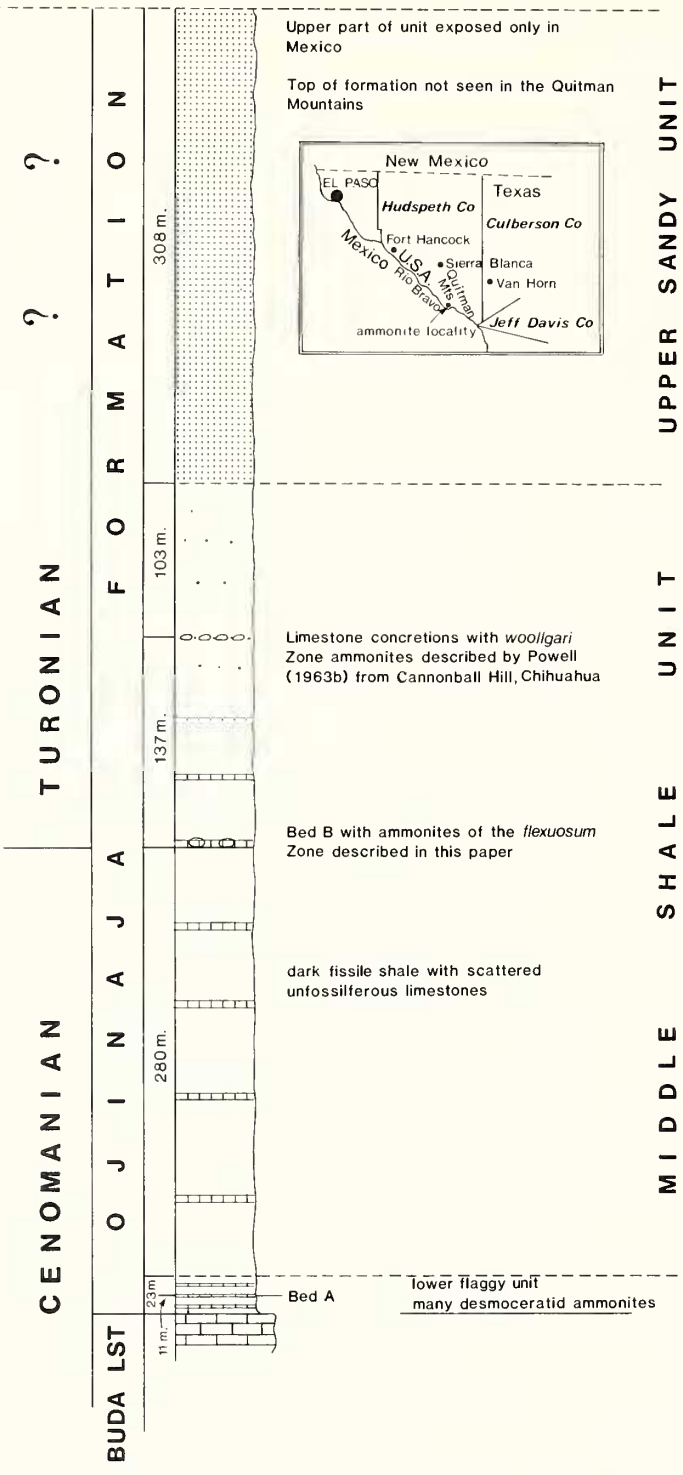


TEXT-FIG. 1. Location map and generalized succession of the Cenomanian–Turonian in the southern Quitman Mountains, Hudspeth County, south-west Texas and Sierra de la Cieneguilla, northern Chihuahua, Mexico. Based on Powell (1963, 1965), Jones and Reaser (1970), and our own observations.

BASAL TURONIAN FAUNA IN WEST TEXAS

Elements of this fauna were noted by Adkins (1933) and Powell (1963) and were subsequently made the basis of a *Pseudaspidoceras flexuosum* Zone by Powell (1965). At present this ammonite–inoceramid fauna is known from a series of localities in the southern Quitman Mountains, Hudspeth County, Texas and in the Sierra de la Cieneguilla, Chihuahua, northern Mexico (text-fig. 1). Powell's original material came from three localities in the Cenomanian–Turonian Ojinaga Formation (text-fig. 1): Arroyo Alamos, near Dos Alamos, 3·25 km east-south-east of Cieneguilla, Municipio de Guadalupe Bravo in northern Chihuahua; Kelsey's Crossing, 1500 m south of the crossing on the Rio Grande on the west side of the Kelsey Ranch, Chihuahua, and scattered outcrops on either side of Goat Canyon Arroyo, 3·25 km west of the Kelsey ranch house, Hudspeth County, Texas. The same fauna occurs abundantly on the east side of Calvert Canyon, from its intersection with the Rio Grande (Rio Bravo) for half a kilometre northwards, 3 km north-west of Love Triangulation Station, where we have hundreds of ammonites and inoceramids from a single bed of brown-weathering black concretions in brown-white weathering black shales.

At Calvert Canyon, the source of the bulk of the material described here, the fauna is limited to less than 50 cm of section (Bed B of Powell's account, a term we retain here for clarity). We have seen only ammonites and inoceramid bivalves plus planktonic foraminifera and calcispheres (some perhaps calcitized radiolarians), the latter in thin section. The ammonites range from complete adults to juveniles (the latter dominate). This fauna plus the organic-rich black shale associated suggest a mass-mortality assemblage preserved under anoxic conditions, and the Ojinaga Formation as a whole records such conditions, with fossils generally lacking. Indeed, the *P. flexuosum* Zone at these localities is in stratigraphic isolation, occurring some 300 m above the top of the Buda Limestone. Elsewhere, however, as in sections in the the Chispa Summit Formation (a lateral equivalent of the Ojinaga) on the Stone (formerly Speck) Ranch, Grayton Lake Quadrangle, Hudspeth County, Texas and between Chispa Summit and Needle Peak, Jeff Davis County, Texas, the zonal fauna occurs in a fossiliferous sequence, and can be shown to occur above a fauna of the *Neocardioceras juddii* Zone, widely regarded as Upper Cenomanian (see Wright and Kennedy 1981; Cobban 1983). This relationship has now been proven at sections in New Mexico and elsewhere in the U.S. Western Interior (Cobban 1983, 1984; Hook and Cobban 1981). The importance of the west Texas *flexuosum* Zone fauna is that it provides a wealth of ammonites (at all ontogenetic stages) of typically Tethyan and Boreal types including species known from as far afield as Montana, California, Venezuela, Nigeria, Tunisia, England, and Czechoslovakia which provide a datum for inter-regional correlation. The associated inoceramids are uncrushed and in an expanded sequence and belong to a form having an even wider distribution than the ammonites. The co-occurrence of these two key groups of biostratigraphic indicators at a critical level in the mid Cretaceous is the justification for the present account. A systematic description of the assemblage follows, after which the inter-regional correlation of this basal Turonian fauna is described.

SYSTEMATIC PALAEONTOLOGY

Location of specimens. This is indicated by the following abbreviations:

OUM, University Museum, Oxford;
USNM, US National Museum, Washington DC.
UTA, University of Texas at Austin Collections, housed in Texas Memorial Museum, Austin, Texas.
BMNH, British Museum (Natural History), London.

Dimensions. Dimensions are given in millimetres, in the following order: diameter (D), whorl breadth (Wb), whorl height (Wh), and breadth of umbilicus (U); c = costal, ic = intercostal measurements. Figures in parentheses refer to dimensions as a percentage of diameter.

Suture terminology. The suture terminology of Wedekind (1916) as amplified by Kullmann and Wiedmann (1970) is followed here: I = Internal lobe; U = Umbilical lobe; L = Lateral lobe; E = External lobe.

Order AMMONOIDEA Zittel, 1884
Superfamily ACANTHOCERATACEAE de Grossouvre, 1894
Family ACANTHOCERATIDAE de Grossouvre, 1894
(name corrected by Hyatt (1900) from Acanthoceratidés de Grossouvre, 1894)
Subfamily ACANTHOCERATINAE de Groussouvre, 1894
Genus QUITMANICERAS Powell, 1963

Type species. Q. reaseri Powell, 1963, p. 313, pl. 32, figs. 5 and 13; text-fig. 3*h*, *j*, by original designation.

Diagnosis. Variable dwarf compressed acanthoceratines retaining or not the full complement of umbilical, inner and outer ventrolateral and siphonal tubercles. In most the siphonal line is raised, producing either a row of fine siphonal clavi or an entire keel. Extreme forms in the young range from nearly smooth oxycones to compressed, parallel-sided individuals with narrow flat venters from the earliest stage seen.

Discussion. Abundant new material of *Q. reaseri* includes on the one hand individuals that are hardly distinguishable in middle growth from compressed *Thomelites* Wright and Kennedy, 1973 of the Upper Cenomanian and on the other hand smooth oxycones that have been questionably identified as *Choffaticeras* Hyatt, 1903. The former type indicates the ancestry of the genus. Some of the keeled forms look forward to *Prohauericeras* Nowak, 1913, a poorly understood genus from the Middle Turonian of France recently discussed by Kennedy *et al.* (1984).

Occurrence. Lower Turonian of Chihuahua, west Texas, New Mexico, Colorado, and Wyoming.

Quitmaniceras reaseri Powell, 1963

Plate 1, figs. 1–38; text-fig. 2A–C

1923 *Pseudotissotia* (*Choffaticeras*) sp.? Reeside, p. 30, pl. 12, figs. 3–6.
1963 *Quitmaniceras reaseri* Powell, p. 313, pl. 32, figs. 5 and 13; text-fig. 3*h*, *j*.
1963 *Quitmaniceras brandi* Powell, p. 314, pl. 32, figs. 6, 8, 11–12, 14–16; text-fig. 3*i*, *p*, *q*.
1977 *Metoicoceras* aff. *whitei* Hyatt; Chancellor, Reyment and Tait, p. 91, fig. 5.
1979 *Quitmaniceras brandi* Powell; Cooper, p. 124.
1982 *Metoicoceras*? sp. Chancellor, p. 83, figs. 5 and 6.

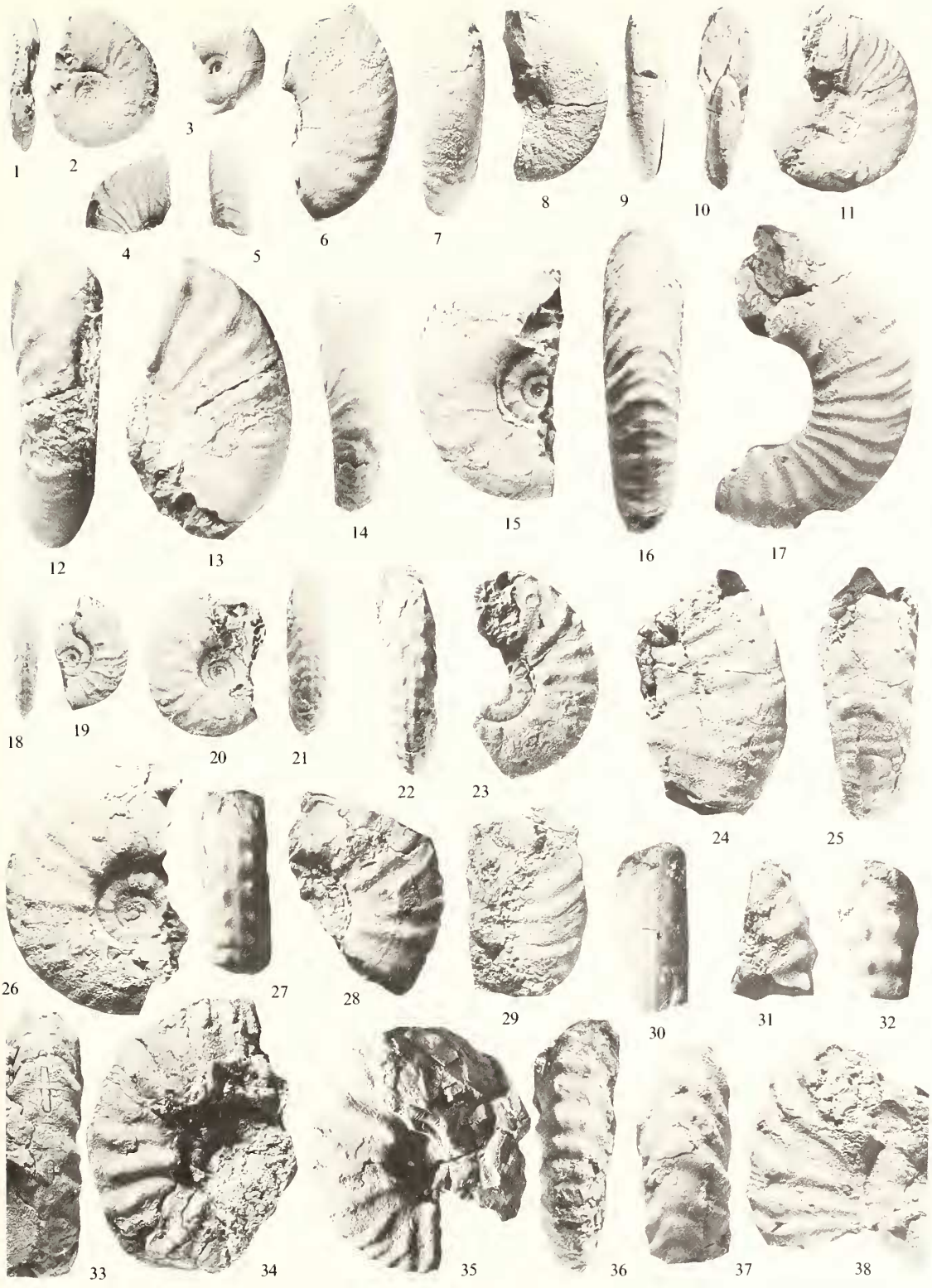
Types. The holotype is UTA 36225 (Pl. 1, figs. 14 and 15) from Bed B of the Ojinaga Formation at Powell's (1963) Dos Alamos locality, Chihuahua, Mexico. There are seventeen paratypes.

Other material. More than 150 specimens in the Oxford University Museum Collections, from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

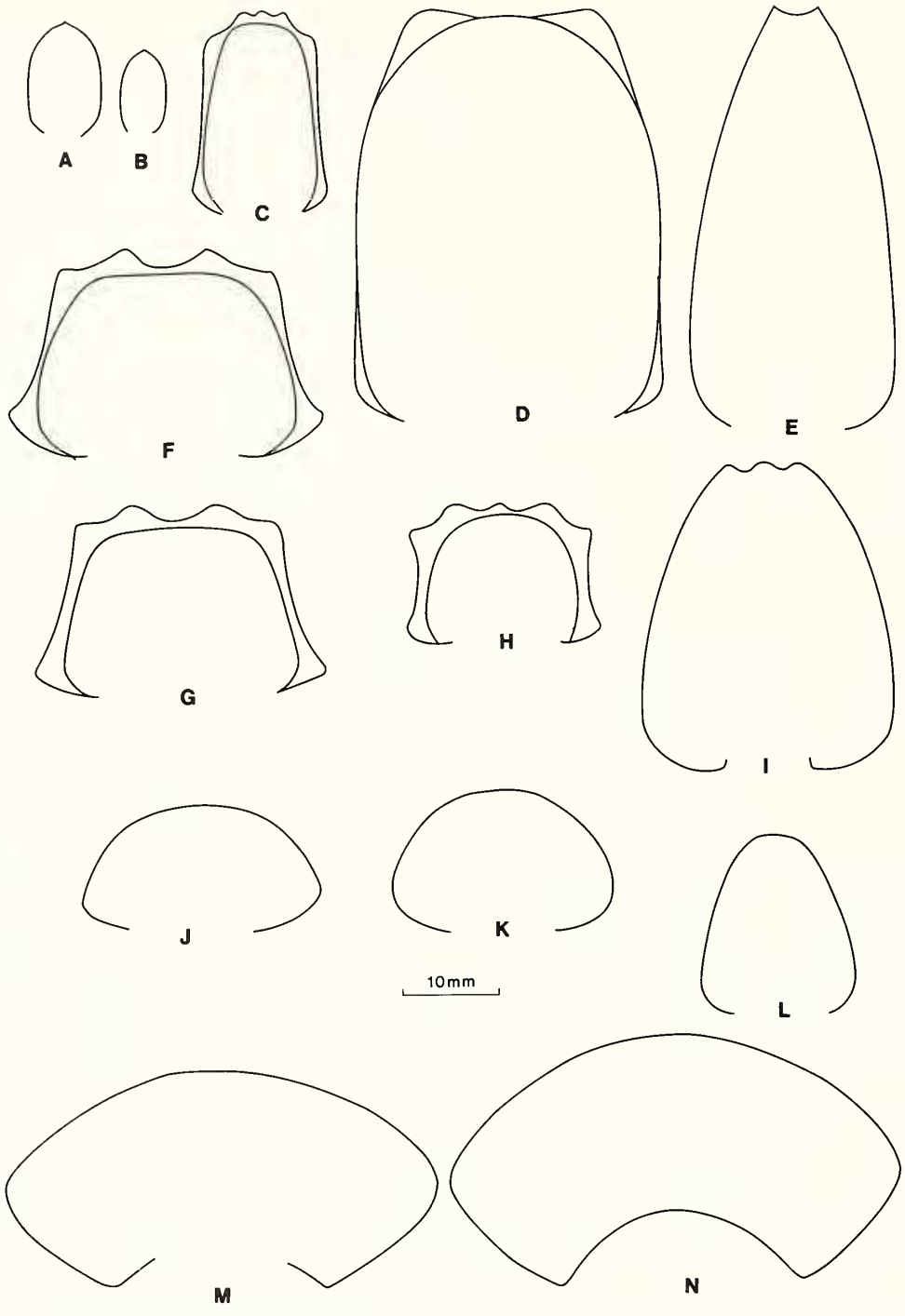
EXPLANATION OF PLATE 1

Figs. 1–38. A variation series of *Quitmaniceras reaseri* Powell, 1963, arranged in order of increasing whorl inflation and strength of ornament, × 1. 1 and 2, OUM KT27; 3, OUM KT986; 4 and 5, OUM KT636; 6 and 7, OUM KT550; 8 and 9, OUM KT634; 10 and 11, OUM KT21; 12 and 13, OUM KT700; 14 and 15, UTA 36225, the holotype; 16 and 17, UTA 36222, the holotype of *Q. brandi* Powell, 1963 (a synonym); 18 and 19, UTA 30917, a paratype of *Q. brandi*; 20 and 21, UTA 36223, a paratype of *Q. brandi*; 22 and 23, OUM KT31; 24 and 25, OUM KT602; 26, OUM KT965; 27 and 28, OUM KT738; 29 and 30, OUM KT517; 31 and 32, OUM KT547; 33 and 34, OUM KT33; 35 and 36, OUM KT590; 37 and 38, OUM KT575.

All specimens are from the Basal Turonian *Pseudaspidoceras flexuosum* Zone fauna of Bed B of the Ojinaga Formation. 1–13, 22–38, from Calvert Canyon, Hudspeth County, Texas; 14–21, from Dos Alamos, in Arroyo Alomos, Chihuahua, Mexico. All figures are × 1.



KENNEDY, WRIGHT and HANCOCK, *Quitmaniceras*



TEXT-FIG. 2. Whorl sections of: A, B, C, *Quitmaniceras reaseri* Powell, 1963, based on OUM KT21, 27, and 33 respectively; D, *Pseudospidoceras flexuosum* Powell, 1963, OUM KT352; E, *Wrightoceras munieri* (Pervinquière, 1907), OUM KT399; F, G, *Mammites powelli* sp. nov., based on OUM KT524 and 714 respectively; H, *Kamerunoceras calvertense* (Powell, 1963), OUM KT545; I, *Thomasites adkinsi* (Kummel and Decker, 1954); J, K, M, N, *Fagesia catinus* (Mantell, 1822), based on OUM KT662, 261, 237, and 246 respectively; L, *Neoptychites* sp., based on OUM KT975.

Dimensions

	D	*Wb*	*Wh*	*Wb*:*Wh*	*U*
OUM KT738	—	10·7(—)	15·7(—)	0·64	—(—)
OUM KT549	20·0(100)	—(—)	7·3(37)	—	6·9(35)
OUM KT774	23·5(100)	6·2(26)	10·0(43)	0·62	7·0(30)
OUM KT751	—(—)	5·5(—)	8·0(—)	0·69	—(—)
OUM KT543	—(—)	13·1(—)	18·7(—)	0·70	—(—)
OUM KT550	—(—)	11·5(—)	15·0(—)	0·76	—(—)
OUM KT638	15·0(100)	3·3(22)	5·0(33)	0·66	5·0(33)
OUM KT700	—(1)	11·7(—)	18·8(—)	0·62	—(—)

Description. Since the material covers a wide morphological range, we describe it by drawing attention to the features of the specimens selected for illustration. At one extreme (Pl. 1, figs. 27–28, 31–38) are moderately evolute, high whorled, and compressed individuals with sides flat and parallel for inner 75 %, then converging to a narrow, flat venter. Strong primary ribs form bullae on the umbilical margin, run straight and rectiradiate to an inner ventrolateral tubercle at which they turn forward to the outer ventrolateral. The ribs cross the narrow venter transversely, slightly depressed on either side of a very feeble siphonal tubercle. Secondary ribs are intercalated irregularly, arising near the umbilical margin or at the level of the inner ventrolateral tubercles; the former have inner and outer and the latter outer ventrolateral tubercles.

At the other extreme (Pl. 1, figs. 1–11) are individuals with a more or less oxyconic whorl section with entire sharp keel and rounded sinuous ribs. These are linked to the coarse ribbed form by the holotype of *Q. reaseri* (Pl. 1, figs. 14 and 15) via specimens such as that shown in Plate 1, figs. 20 and 21, the holotype of *Q. brandi* (Pl. 1, figs. 16 and 17), and the individuals shown in Plate 1, figs. 27 and 28. The very simple, little-incised sutures are poorly exposed in all our material.

Discussion. Powell (1963, p. 314) distinguished *Q. brandi* from *Q. reaseri* on the basis of the former having ribbed innermost whorls, stronger tuberculation, and less irregular ribbing. Our abundant material, albeit fragmentary in many cases, suggests a spectrum whose morphological range goes a little further than that indicated by Powell both in the direction of feebly ornamented oxycones and robust individuals with regular strong tuberculation, but which does not appear to have significant gaps. We therefore unite Powell's two species.

Occurrence. Basal Turonian of Loma el Macho and Dos Alamos, Chihuahua, Mexico; Calvert Canyon, Stone Ranch, and Chispa Summit, west Texas; New Mexico and Montana.

Subfamily EUOMPHALOCERATINAE Cooper, 1978
Genus KAMERUNOCERAS Reyment, 1954

Type species. Acanthoceras eschii Solger, 1904, p. 124, pl. 4, figs. 1–4, by original designation.

Discussion. A full revision of *Kamerunoceras* has recently been given by Kennedy and Wright (1979*b*).

Occurrence. Uppermost Cenomanian to Middle Turonian of England; Turonian of France, Spain, north Africa, the Middle East, Nigeria, Cameroon, Madagascar, Mexico, west Texas and the US Western Interior, Brazil, and Venezuela.

Kamerunoceras calvertense (Powell, 1963)

Plate 3, figs. 15–18; text-fig. 2H

1963 *Acanthoceras calvertense* Powell, p. 315, pl. 33, figs. 8 and 9; pl. 34, figs. 6 and 9; text-fig. 2*e* (? *non* pl. 33, figs. 8 and 9).

1963 *Acanthoceras* sp. Powell, p. 316, pl. 33, fig. 5; text-fig. 5*d*.

Types. The holotype is UTA WSA227 from Babb Ranch in the Southern Quitman Mountains, and there are three paratypes from Bed B of the Ojinaga Formation at Powell's (1963) Arroyo Alamos locality, Chihuahua, Mexico.

Other Material. OUM KT405, 417, 426, 429, 435, 437, 545, 679, 733, 976, 978–979, all from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Description. The present material consists chiefly of fragments of inner whorls with diameters of 40 mm or less, with only one larger fragment, OUM KT405. They have a more or less square intercostal section, distant primary ribs with strong umbilical and strengthening inner ventrolateral spines, slightly weaker clavate outer ventrolaterals, and feeble siphonal clavi; secondary ribs carry inner and outer ventrolateral and siphonal tubercles. Below a diameter of 20 mm the tubercles are relatively weaker and the costal whorl section consequently more rounded; occasional supernumerary ribs are present on the venter. The single large fragment shows a broad, nearly flat venter with weakening primary ribs, slightly adorally convex, with feeble traces of inner ventrolateral and siphonal tubercles.

The suture line is relatively simple, with broad bifid lobes and saddles.

Discussion. The smaller specimens closely resemble acanthoceratine nuclei from the Upper Cenomanian. They also compare very well with the inner whorls of *Kanabiceras puebloense* as figured by Cobban and Scott (1972) if those distorted specimens are restored to their natural shape. The larger fragment agrees well with the body-chamber of an English specimen compared with *puebloense* (Wright and Kennedy 1981, p. 56, pl. 14, figs. 3 and 11). Powell's holotype and figured paratype (1963, pl. 34, figs. 6 and 9) of *A. calvertense* show a phase between our smaller specimens and OUM KT405. Another paratype, UTA 5525 (Powell 1963, pl. 33, figs. 8 and 9; see Pl. 3, figs. 17 and 18) differs in having fine untuberculate secondaries between primaries, although this may be merely a matter of preservation. Apart from this specimen, all the material before us seems to belong to a single species.

Cobban and Scott's (1972) *K. puebloense* is based on crushed composite internal moulds, and this makes comparison with *K. calvertense* difficult. *K. puebloense* was characterized by its regular ribbing, with nine to sixteen ribs across the venter per half whorl and prominent inner ventrolateral tubercles that show a tendency towards spinosity. This tendency is seen in some of our specimens, but the different preservation means that in our material the tips of the septate spines are lost beyond the basal septum, as is common in ancestral *Euomphaloceras*. The rib densities of the two groups of specimens are very similar, and given differences in size and preservation might be within the range of a single variable species, the trivial name *calvertense* having priority. Dr W. A. Cobban points out, however, that *K. calvertense* is significantly older than *K. puebloense*, is much more robust, more involute, and more delicately ornamented and lacks the spinose inner whorls.

Occurrence. Lower Turonian of northern Chihuahua and Calvert Canyon and the southern Quitman Mountains, west Texas.

Genus PSEUDASPIDOCERAS Hyatt, 1903
(= *Ampakabites* Collignon, 1965)

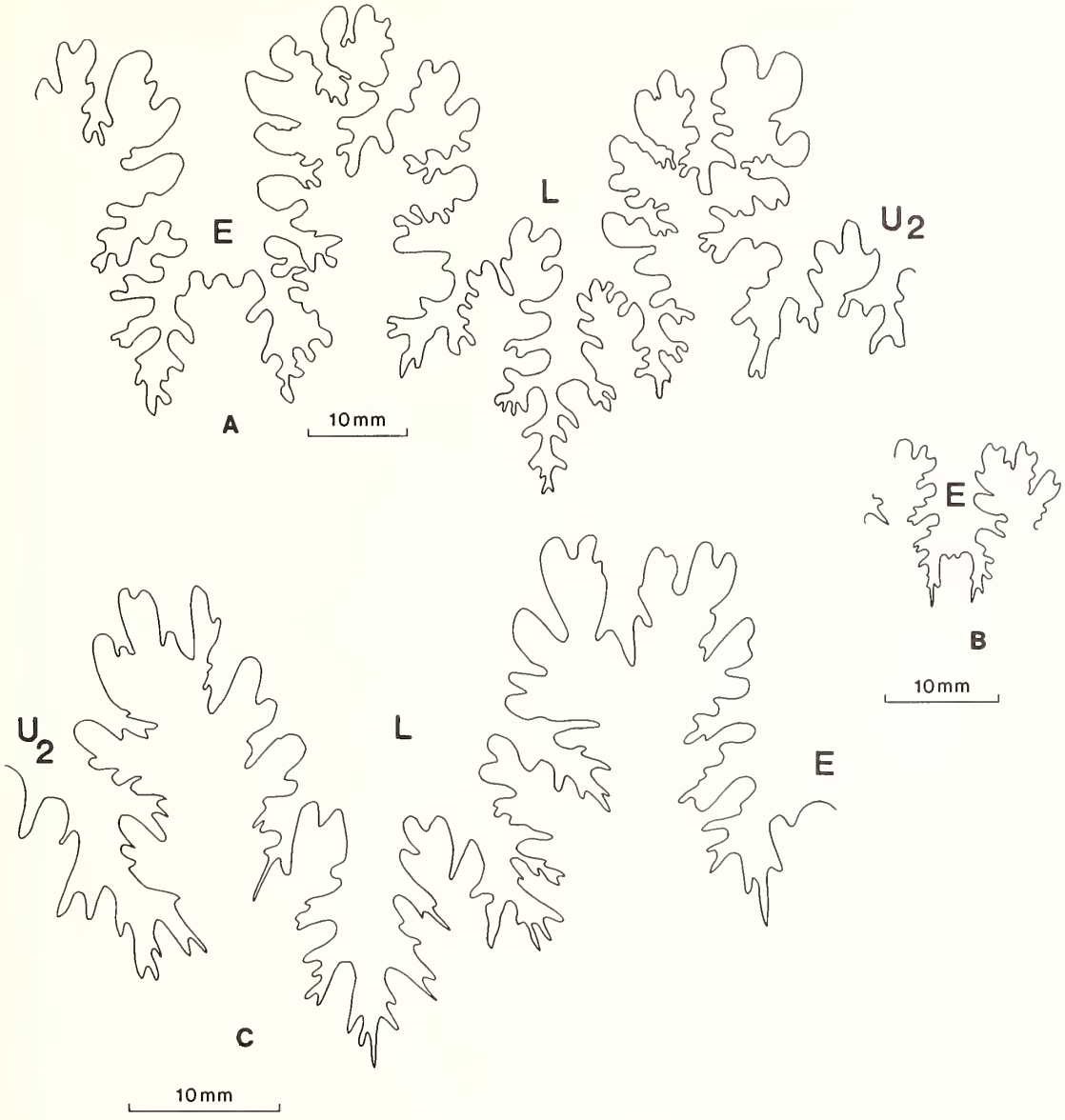
Type species. By original designation, *Ammonites footeanus* Stoliczka, 1864, p. 101, pl. 52, figs. 1 and 2. See text fig. 4.

Discussion. See discussion under *P. flexuosum* Powell, 1963 below.

Pseudaspidoceras flexuosum Powell, 1963

Plate 2, figs. 1–4, 8–13, 16–17; text-figs. 3A–C, 5, 6C, D, 7A–C

1902 *Mammites footeanus* Stol. spec.; Petrascheck, p. 144, pl. 9, fig. 1.
1920 *Pseudaspidoceras* aff. *pedroanum* White; Böse, p. 209, pl. 13, fig. 1. pl. 15, fig. 1.
1957 *Pseudaspidoceras paganum* Reyment; Barber, p. 11 (*pars*).
1963 *Pseudaspidoceras flexuosum* Powell, p. 318, pl. 32, figs. 1, 9–10; text-fig. 2*a–c*, *f*, *g*.
1965 *Kamerunoceras* (*Ampakabites*) *auriculatum* Collignon, pp. 29, 31; pl. 388, fig. 1662; pl. 389, fig. 1664 (*auriculatus* on pp. 31–32).
1972 *Ampakabites collignoni* Cobban and Scott, p. 81, pl. 29, figs. 1–3; text-figs. 39 and 40.



TEXT-FIG. 3. External sutures of *Pseudaspidoceras flexuosum* Powell, 1963. A is based on the lectotype of *Ampakabites auriculatus* Collignon, 1964; B on OUM KT411; C on OUM KT352.

1978 *Pseudaspidoceras flexuosum* Powell; Young and Powell, pl. XXV.2, figs. 8–10.
1978 *Pseudaspidoceras* aff. *footeanum* Petrascheck, 1902; Young and Powell, pl. 3, fig. 16.

Types. The holotype is UTA 30842 and there are thirty-nine paratypes from Bed B of the Ojinaga Formation at Powell's (1963, p. 310) Kelsey Crossing locality, Hudspeth County, Texas.

Other material. We have the following specimens from Bed B of the Ojinaga Formation in Calvert Canyon, Hudspeth County, Texas: OUM KT188–204, 206–207, 352, 403, 407, 411, 413, 415, 422–423, 436, 533, 536, 656, 697, 707, 737, 753, 966, 989, 990.

TEXT-FIG. 4. Plaster cast of the lectotype of *Pseudaspidoceras footeanum* (Stoliczka, 1864), GSI 213. The original specimen was figured by Stoliczka 1864 as his pl. 52, fig. 1, and is from the Utatur Group north of Odium, southern India; ×0·45.

Description. Up to 20 mm diameter: The shell is rather evolute, with a moderately deep, fairly wide umbilicus. The umbilical walls are steep, with evenly rounded shoulders. The flanks are rather broad and flat, with an arched venter. Very weak, slightly prosiradiate ribs arise at about mid-flank and give rise to seven weakly clavate ventrolateral tubercles per whorl. Across the venter the ribs are arched strongly forwards, with a hint of weak looping. The posterior (adapical) rib, when they are looped, is ornamented with two minute, bubble-like nodes, closely spaced on either side of the

EXPLANATION OF PLATE 2

Figs. 1–4, 8–13, 16–17. *Pseudaspidoceras flexuosum* Powell, 1963. 1 and 2, UTA 37124; 3 and 4, OUM KT413; 8 and 9, OUM KT206; 10 and 11, OUM KT737; 12 and 13, OUM KT411; 16 and 17, OUM KT352.

Figs. 5–7. *Sciponoceras* sp. OUM KT652.

Figs. 14 and 15. Mammitinae gen. et. sp. indet. OUM KT329.

All specimens are from the Basal Turonian *P. flexuosum* Zone fauna of Bed B of the Ojinaga Formation; 1 and 2, from the Dos Alamos in Arroyo Alamos, Chihuahua, Mexico; the remainder are from Calvert Canyon, Hudspeth County, Texas. Figs. 1–7, ×2; figs. 8–17, ×1.

KENNEDY, WRIGHT and HANCOCK, *Pseudaspidoceras*, *Sciponoceras*, Mammitinae

siphonal line. Occasional specimens have stronger, finer ribs, some of which originate from weak umbilical bullae, as well as lower ventrolateral tubercles intercalated between the main ribs and looped across the venter, but lacking the upper ventrolateral nodes found on the main ribs.

20–50 mm diameter: A number of specimens (OUM KT207, 411, 737) represent this growth stage. OUM KT207 (Text-fig. 6C) shows that the main ribs are now all ornamented with weak umbilical bullae, whilst the inner ventrolateral tubercles are much more prominent and almost conical. OUM KT737 (Pl. 2, figs. 10 and 11) shows that the weak flank ribs are slightly prorsiradiate, with a faint adorally-convex curvature, and that frequently two ribs arise from a single umbilical bulla, with one of them generally becoming obsolete before reaching the venter. There are six umbilical bullae per half-whorl at this stage and eight inner ventrolateral tubercles.

OUM KT411 (Pl. 2, figs. 12 and 13) has the ventral region well preserved and shows prominent looping of the ribs across the venter. Between the pair of looped ribs the interspace is unusually deep, giving the impression that constrictions are present, although this probably is not the case. In this specimen the inner ventrolateral tubercles are becoming distinctly clavate whilst, across the venter, intercalated ribs show weak bullate swellings on either side of the siphonal line, so that there are far more outer than inner ventrolateral tubercles, giving the specimen a markedly *Euomphaloceras*-like appearance.

OUM KT204 at 55 mm diameter shows considerably weaker ornament than OUM KT411, and there is clearly much variation in this respect. In OUM KT206, ribs are virtually absent and ornament comprises irregular weak folds and growth striae and the ventrolateral tubercles. Across the venter, ribs are lacking but the deepened interspaces between looped ribs (immediately in front of the outer ventrolateral nodes) still remain.

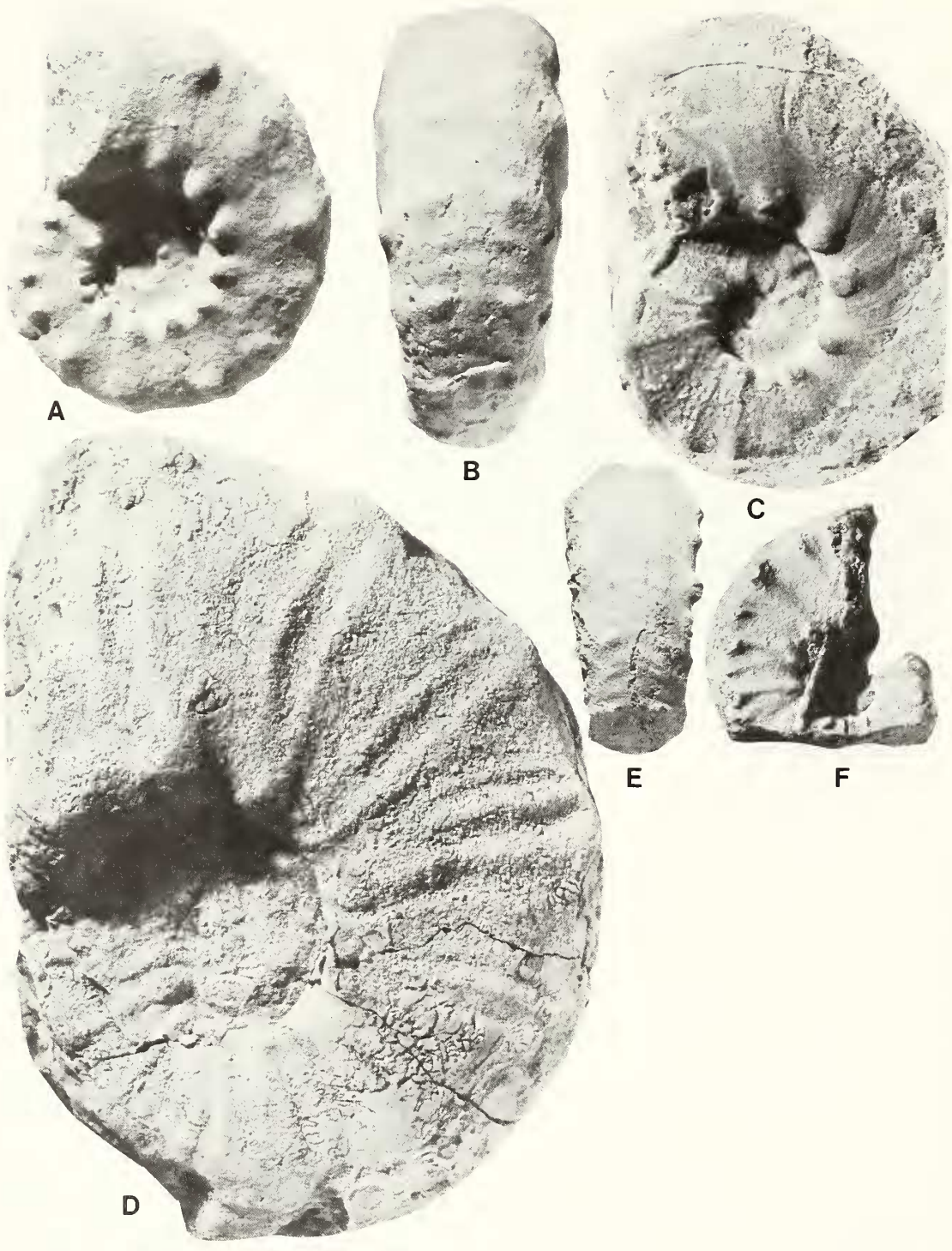
50–300 diameter: At this growth stage (Pl. 2, figs. 16 and 17; text-figs. 6C and 7), the whorl section is rectangular, compressed, the umbilical wall is slightly overhanging with an abrupt, evenly rounded umbilical shoulder. The flanks are broad and flattened, subparallel, and the venter is slightly convex. Ornament comprises distinct umbilical bullae, four per quarter whorl, which give rise to very weak ribs, either singly or in pairs. The ribs are initially distinctly prorsiradiate, but flex back at about mid-flank to become rectiradiate. There may be up to two very weak intercalatories between main ribs. Main ribs are ornamented with weak, clavate ventrolateral tubercles which are joined across the venter by strongly arched, adorally convex ribs which still show a tendency to be looped. The outer ventrolateral nodes have normally disappeared by the beginning of this stage.

The external suture line (text-fig. 3B, C), consists of a narrow E, deep, asymmetrically trifid L, narrow E/L and L/U_2.

Discussion. The holotype is a medium-sized body-chamber fragment. This and larger specimens (text-fig. 7) before us suggest considerable variation in adults of this species, sufficient to encompass the Czech specimen figured by Petrascheck (1902), the types of *Kamerunoceras* (*Ampakabites*) *auriculatum* Collignon 1965 (text-figs. 5, 6D), and perhaps *Ampakabites collignoni* Cobban and Scott, 1972. Cobban and Scott distinguished the single specimen of *A. collignoni* from *K. auriculatum* by its 'more arched venter, greater number of umbilical and ventrolateral tubercles, and a third row of tubercles on the flank'. The arching of the venter in *collignoni* is clearly due to crushing, the slightly greater rib and therefore tubercle density does not seem to us to be significant in this variable species and the feeble inner ventrolateral tubercles of *collignoni* are not markedly stronger than those visible in the types of *auriculatus* (text-figs. 5, 6D). The lectotype of *Pseudaspidoceras footeanum* (Stoliczka, 1865) (pl. 52, fig. 1) (text-fig. 4) has a squarer whorl section and straighter ribs which distinguish it from the present form at specific level, but they appear to be congeneric. Wright and Kennedy (1981, p. 81) pointed out that the outer whorls of the two species were closely similar but that the inner whorls of *flexuosum* were very different from the *Mammites*-like inner whorls of the lectotype of *footeanum*. Subsequent examination of a plaster cast of this specimen makes it very doubtful that the inner whorls figured by Stoliczka (1865, pl. 52, fig. 1*a*, *b*) actually belong to the specimen in that figure. If they do, the figure is much restored and incorrectly so. The innermost whorls visible in the plaster cast of the lectotype show distant ribs comparable with those

TEXT-FIG. 5. The paralectotype of *Kamerunoceras* (*Ampakabites*) *auriculatum* Collignon, 1964, the original of Collignon 1964 pl. 389, fig. 1664, from the Lower Turonian of Ampakabo (Betioky), Madagascar. Collignon Collection, Université de Dijon; × 1.

of *flexuosum*. Moreover, its outer whorls can be seen to have feebly looped primary ribs of the type characteristic of *flexuosum*. *Mammites* (*Pseudaspidoceras*) *dubertreti* Basse, 1937 (p. 183, pl. 10, fig. 3*a*, *b*; pl. 11, fig. 2) may also belong to this genus. It too is distinguished by having straight rather than flexuous ribs at a comparable growth stage.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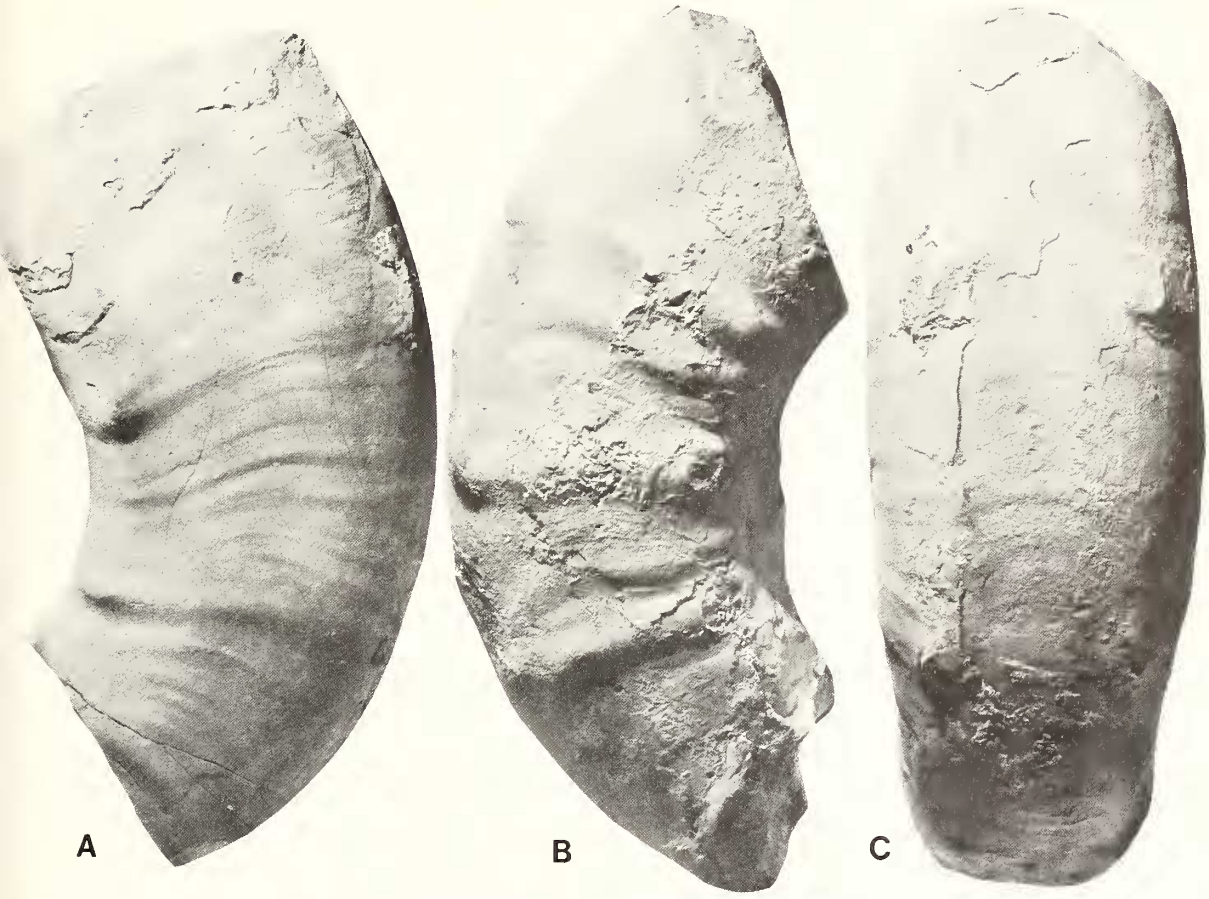


TEXT-FIG. 7. A–C, *Pseudaspidoceras flexuosum* Powell, 1963. Adult body-chambers from the Basal Turonian *P. flexuosum* Zone of Calvert Canyon, ×0·5. A, C, OUM KT149; B, OUM KT199.

Occurrence. Lower Turonian of west Texas, northern Mexico, ?Colorado, the German Democratic Republic, Nigeria, and Madagascar.

Subfamily MAMMITINAE Hyatt, 1900
(= Metoicoceratidae Hyatt, 1903; Fallotitinae Wiedmann, 1960)

Discussion. See Wright and Kennedy 1981, p. 62.

TEXT-FIG. 6. A, B, E, F, *Pseudaspidoceras pseudonodosoides* (Choffat, 1898); A, B, USNM 337482, from the *Neocardioceras juddii* Zone at USGS Mesozoic locality D10114 in NE 1/4 section 13, Township 21S, Range 9W, Luna County, New Mexico; E, F, OUM KY1095, from the upper part of the *Paravascoceras cauvini* Zone of Freund and Raab (1969), Ora Formation, roadside section on south side of Mishor Seifim, 18 km N. of Elat, Negev, Israel. C, D, *Pseudaspidoceras flexuosum* Powell, 1963; C, silicone squeeze taken from an external mould, OUM KT207, from the Lower Turonian *P. flexuosum* Zone of Calvert Canyon; D, the lectotype of *Kamerunoceras* (*Ampakabites*) *auriculatum* Collignon, 1964, the original of Collignon 1964, pl. 358, fig. 1662, from the Lower Turonian of Ampakabo (Betioky), Madagascar; Collignon Collection, Université de Dijon collections. All figures are ×1.

Genus MAMMITES Laube and Bruder, 1887
(= *Schluetericeras* Hyatt, 1903)

Type species. Ammonites nodosoides Schlüter, 1871, p. 19, pl. 8, figs. 1–4, by monotypy.

Discussion. See Wright and Kennedy 1981, p. 75 for a full review of this genus.

Occurrence. Turonian, widespread in Eurasia, West Africa, and North and South America.

Mammites powelli sp. nov.

Plate 3, figs. 1–14; Plate 4, figs. 16 and 17, text-fig. 2F, G

1963 *Mammites nodosoides* (Schlotheim); Powell, p. 316, pl. 33, figs. 1, 3, 4, 6, 10, 11; text-fig. 3*m–o*, *t*, *u*.

1978 *Mammites nodosoides* (Schlotheim); Young and Powell, pl. 2, fig. 2.

Types. The holotype is OUM KT404; paratypes are OUM KT205, 408, 412, 421, 425, 431, 434, 438, 524, 527, 534, 541, 678, 703, 714, 724, 968–970. All specimens are from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Origin of Name. For J. Dan Powell, who first described the Calvert Canyon fauna.

Description. A small, evolute, coarsely ribbed *Mammites* with slightly depressed subquadrate to subtrapezoidal whorl section. There are about twenty ribs to a whorl, of which seven or eight are primaries. All ribs bear inner and outer ventrolateral clavi, which on the mature body-chamber coalesce and finally form prominent ear-shaped ventrolateral bullae which almost join across the venter. The umbilical wall is rounded and slightly undercut.

The rather simple sutures are too poorly exposed for description.

Discussion. M. powelli differs from *M. nodosoides* (Schlüter, 1871) in being much smaller and in lacking the exaggerated ventrolateral horn directed upwards and outwards on the last whorl. *Morrowites* species, e.g. *M. wingi* (Morrow, 1935) (p. 467, pl. 51, fig. 2; pl. 52, fig. 2*a–c*; text-fig. 2) of which *M. chouberti* (Collignon, 1967) (p. 41, pl. 22, figs. 1, 1*a*) and *M. costatus* (Matsumoto and Kawashita, 1978) (p. 5, pl. 1, figs. 1 and 2; pl. 2, figs. 1 and 2; text-fig. 1–3) are probably synonyms, are also large, coarsely ornamented species with broad flat venters and outward directed ventrolateral horns in maturity. *Morrowites* nuclei are constricted.

M. depressus Powell, 1963 (see Cobban and Hook 1979) is a large, very evolute Middle Turonian species with a depressed whorl section much wider than high.

M. dixeyi Reyment (1955, p. 50, pl. 9, fig. 4; pl. 11, fig. 2; text-figs. 20 and 21) of which *M. mutabilis* Reyment, 1955 (p. 51, pl. 10, fig. 1*a*, *b*) is probably a synonym, is mature at about the same size and is closely related to the present species. It differs in having more outer than inner ventrolateral tubercles and in not developing the long ventrolateral bullae on the mature body-chamber.

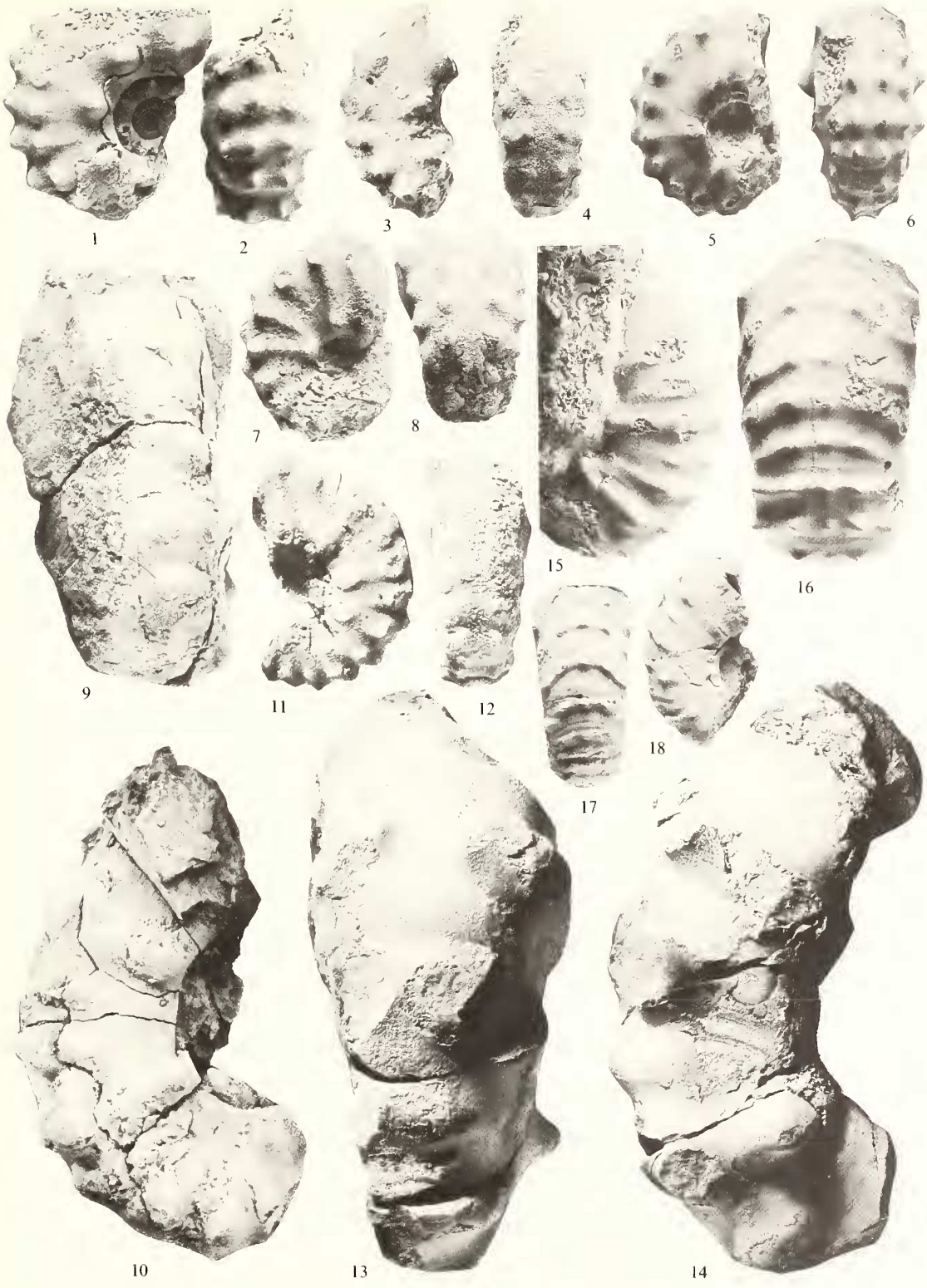
Occurrence. Apart from the type occurrence, the species occurs at Dos Alamos, Chihuahua, northern Mexico and Chispa Summit, Jeff Davis County, Texas. There is a specimen in the British Museum from the Turonian of Novo Redondo, Angola.

EXPLANATION OF PLATE 3

Figs. 1–14. *Mammites powelli* sp. nov. 1 and 2, UTA 35524; 3 and 4, UTA 35532; 5 and 6, UTA 35539; 7 and 8, UTA 30968; 9 and 10, paratype, OUM KT524; 11 and 12, paratype OUM KT969; 13 and 14, the holotype, an adult body-chamber, OUM KT404.

Figs. 15–18. *Kamerunoceras calvertense* (Powell, 1963). 15 and 16, paratype UTA 35526; 17 and 18, paratype UTA 35525.

All specimens are from the Basal Turonian *Pseudaspidoceras flexuosum* Zone fauna of Bed B of the Ojinaga Formation. 1–8, 15–18, from Dos Alamos in Arroyo Alamos, Chihuahua, Mexico; 9–14, from Calvert Canyon, Hudspeth County, Texas. Figs. 1–8, 11–12, × 2; figs. 9–10, 13–18, × 1.



KENNEDY, WRIGHT and HANCOCK, *Mammites*, *Kamerunoceras*

Mammitinae gen. et sp. indet.

Plate 2, figs. 14 and 15

Material. Two fragments, OUM KT329 and 416, from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Description. The material assigned here comprises two very small fragments which show a subquadrate whorl section with flattened, subparallel flanks and a slightly convex venter. Ornament comprises prominent, rounded, slightly prorsiradiate main ribs separated by one to two intercalatories. At the ventrolateral shoulders the ribs flex forwards and pass strongly across the venter, where they are prominently raised, forming a linguoid adorally-convex arch. The ribs are wider than the interspaces. Some ribs show the faintest hint of umbilical bullae, but there is no sign of any other tuberculation.

Discussion. The present material shows features unlike those of any described genus of Turonian ammonite, but is reminiscent of the body-chamber ornament of certain *Protacanthoceras* species (Wright and Kennedy 1980). Until adequate material is available we consider the material generically indeterminate.

Family VASCOCERATIDAE H. Douvillé, 1912
(name corrected and translated by Spath, 1925, from Vascoceratinés H. Douvillé, 1912).

Discussion. See Wright and Kennedy 1981, p. 84.

Subfamily VASCOCERATINAE H. Douvillé, 1912
Genus VASCOCERAS Choffat, 1898
(= *Paravascoceras* Furon, 1935; *Pachyvascoceras* Furon, 1935; *Paracanthoceras* Furon, 1935; *Broggiiceras* Benavides-Cáceres, 1956; *Discovascoceras* Collignon, 1957; *Provascoceras* Cooper, 1979).

Type species. Vascoceras gamai Choffat, 1898, p. 54, pl. 7, figs. 1–4; pl. 8, fig. 1; pl. 10, fig. 2; pl. 21, figs. 1 and 5, by the subsequent designation of Roman 1938, p. 452.

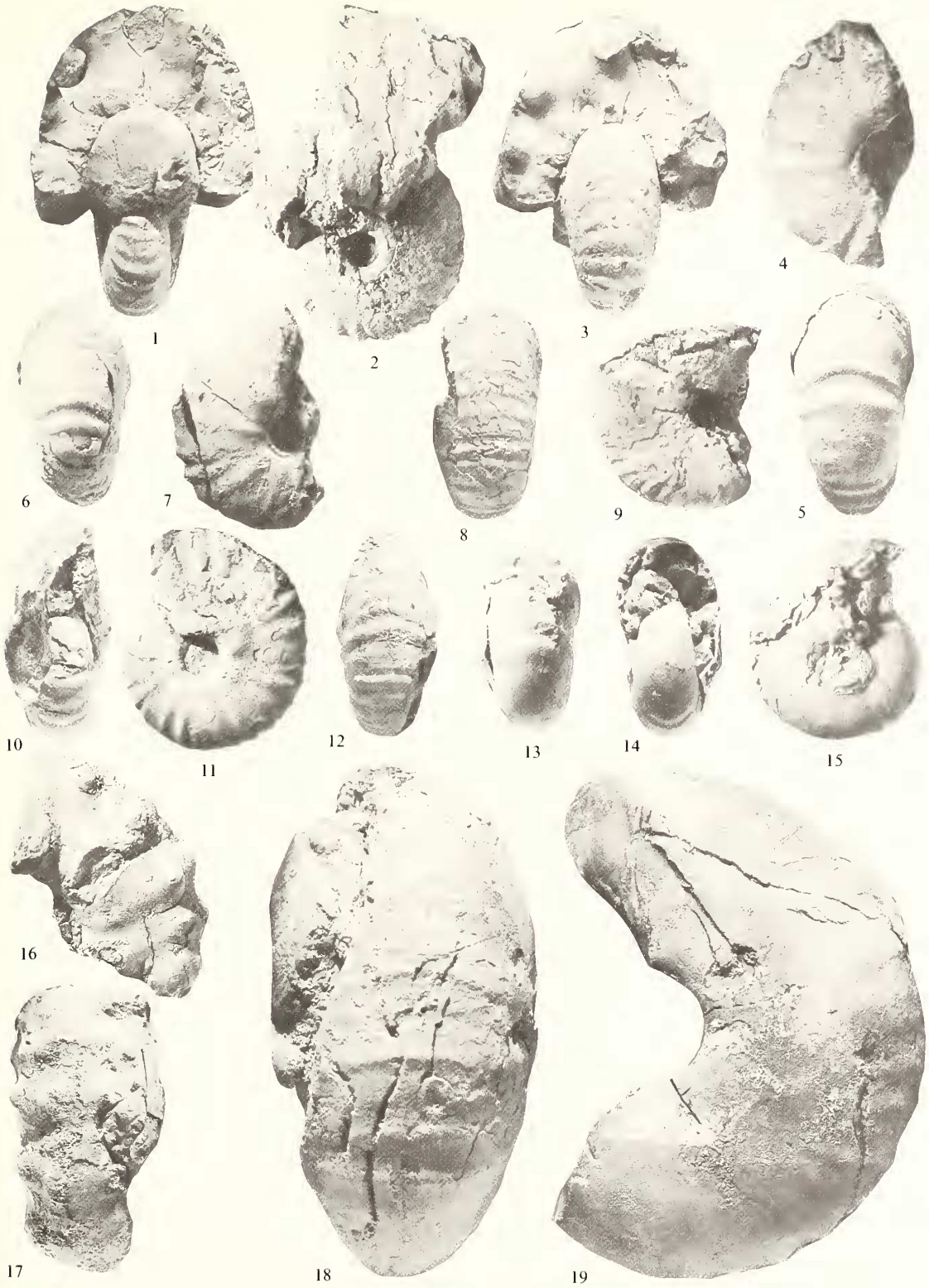
Discussion. Inspection of any large fauna of *Vascoceras* or of any of the many published descriptions of such faunas shows that shell shape and ornament vary widely and, if there are enough specimens, continuously. By picking out and figuring individuals at intervals through the morphological spectrum it is easy to give an impression of a wealth of species or subspecies or even genera or subgenera. The Calvert Canyon material studied here, abundant, uncrushed, and from a single narrow horizon, makes it perfectly clear that there is present but one variable population of *Vascoceras*, ranging from rare smooth cadicones through abundant intermediates to rare ventrally ribbed, moderately compressed specimens with rectangular whorl section, the whole population being linked together by a comparable degree of involution. As a result of the wide variation in this and other populations, there seems no point in separating off segments into the genera noted above.

EXPLANATION OF PLATE 4

Figs. 1–15, 18–19. *Vascoceras proprium* (Reyment, 1954). 1–3, OUM KT992, a juvenile with slender, strongly ribbed inner whorls; 4 and 5, OUM KT480, a nucleus showing the strong constrictions and associated ribs at this stage of development; 6 and 7, OUM KT278, showing the succeeding ribbed stage; 8 and 9, OUM KT613, a relatively finely ribbed juvenile with flattened venter; 10–12, OUM KT272, a juvenile with well-differentiated primary and secondary ribs; 13–15, OUM KT589, showing innermost smooth whorls followed by constricted stage; 18 and 19, OUM KT366, a body-chamber of a possible microconch.

Figs. 16 and 17. *Mammites powelli* sp. nov. Paratype, OUM KT417.

All specimens are from the Basal Turonian *Pseudaspidoceras flexuosum* Zone fauna of Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas. Figs. 4–7, 13–15, × 2; the remainder are × 1.



KENNEDY, WRIGHT and HANCOCK, *Vascoceras*, *Mammites*

Occurrence. Upper Cenomanian and Lower Turonian. Generally Tethyan in occurrence, but a few occur in higher and lower latitudes.

Vascoceras proprium (Reyment, 1954*b*)

Plate 4, figs. 1–15, 18–19; Plates 5–6; text-figs. 8A–C, 9

1920 *Vascoceras angermanni* Böse, p. 217, pl. 16, figs. 1 and 3 (*non* 2 and 4); pl. 17, fig. 1.
1920 *Neoptychites* aff. *cephalotus* (Courtiller); Böse, p. 221, pl. 18, figs. 3, 10, 13.
1931 *Thomasites* sp. Adkins, p. 56, pl. 2, figs. 16 and 17.
1954*b* *Pachyvascoceras proprium* Reyment, p. 258, pl. 5, fig. 1; text-fig. 3*d*.
1954*b* *Pachyvascoceras proprium plenum* Reyment, p. 258, pl. 5, fig. 5; text-figs. 3*c* and 6.
1954*b* *Pachyvascoceras costatum* Reyment, p. 257, pl. 3, fig. 6; pl. 4, fig. 3; pl. 5, fig. 2; text-figs. 3*a–b*, 5.
1954*b* *Pachyvascoceras globosum* Reyment, p. 259, pl. 3, fig. 3; pl. 5, fig. 4; text-figs. 3*c* and 7.
1955 *Paravascoceras costatum* Reyment, p. 65, pl. 14, figs. 2 and 4.
1957 *Vascoceras globosum globosum* (Reyment); Barber, p. 21, pl. 7, fig. 1; pl. 9, fig. 4; pl. 28, figs. 1 and 2.
1957 *Vascoceras globosum plenum* (Reyment); Barber, p. 23, pl. 7, fig. 2; pl. 9, fig. 2; pl. 28, figs. 3–5.
1957 *Vascoceras globosum proprium* (Reyment); Barber, p. 25, pl. 7, fig. 3; pl. 28, figs. 6 and 7.
1957 *Vascoceras globosum compressum* Barber, p. 25, pl. 7, fig. 4; pl. 9, fig. 1; pl. 28, figs. 10 and 11.
1957 *Vascoceras globosum carteri* Barber, p. 25, pl. 8, fig. 2; pl. 28, figs. 8 and 9.
1957 *Paravascoceras costatum costatum* (Reyment); Barber, p. 35, pl. 14, fig. 1; pl. 32, figs. 1–3.
1957 *Paravascoceras costatum tectiforme* Barber, p. 37, p. 14, fig. 4; pl. 15, figs. 1–3; pl. 16, fig. 1; pl. 32, figs. 4–7.
1963 *Pachyvascoceras compressum* Barber; Powell, p. 321, pl. 32, figs. 2–4, 7; pl. 34, figs. 8 and 10; text-fig. 3*b–d, f*.
1963 *Pachyvascoceras globosum* Reyment; Powell, p. 321, pl. 34, figs. 7–11; text-fig. 3*s*.
1977 *Paravascoceras carteri* (Barber); Chancellor, Reyment and Tait, p. 92, figs. 15–17.
1982 *Paravascoceras carteri* (Barber); Chancellor, p. 102, figs. 35–37.
?1982 *Paravascoceras compressum* (Powell not Barber); Chancellor, p. 106, figs. 49 and 50.

Holotype. BMNH C47302 from the Lower Turonian of Gulani, Gongola Valley, Bornu Province, Nigeria.

Material. More than sixty specimens in the Oxford University Museum Collections, from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Dimensions.

	D	*Wb*	*Wh*	*Wb:Wh*	*U*
OUM KT369	54·8(100)	35·0(63·7)	25·8(47·1)	1·36	7·5(13·7)
OUM KT378	74·0(100)	80·0(1·08)	32·5(43·9)	2·46	16·0(21·6)
OUM KT376	120·0(100)	87·0(72·5)	57·5(47·9)	1·51	18·3(15·4)

Description. Specimens of all whorl sections are relatively involute; the umbilical diameter ranges from 13 % to 22 % of total diameter. The umbilical wall is vertical to slightly undercut, with a well-rounded umbilical shoulder. The whorl section is variable, from slightly compressed, flat, and parallel sided with evenly rounded to almost flat venter, to depressed and increasingly cadicone (see Pl. 5). After an initially smooth, moderately compressed stage (Pl. 4, figs. 13–15), constrictions appear at a diameter of 7 or 8 mm (Pl. 4, figs. 4–12), three or four to a whorl, deepest on the outer

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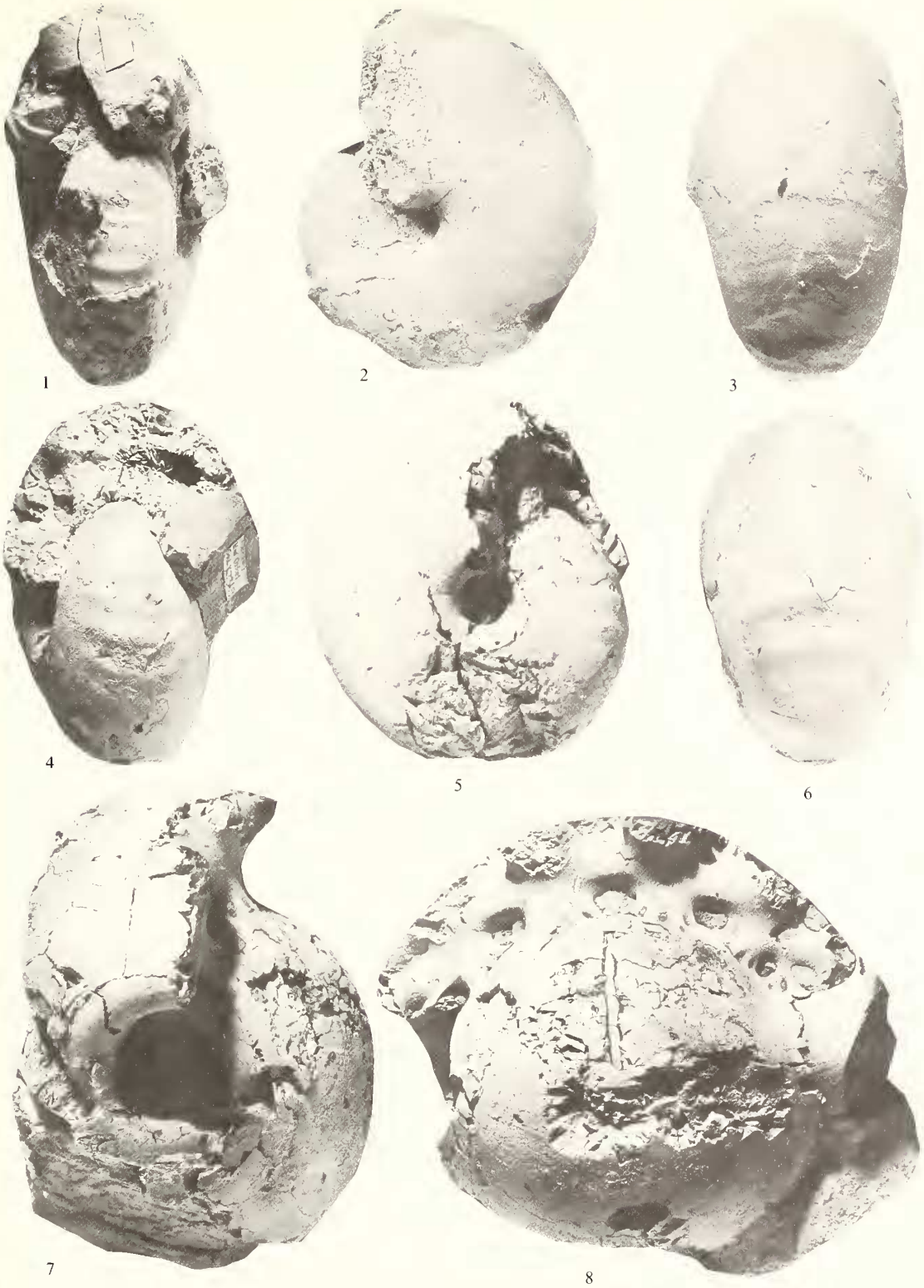
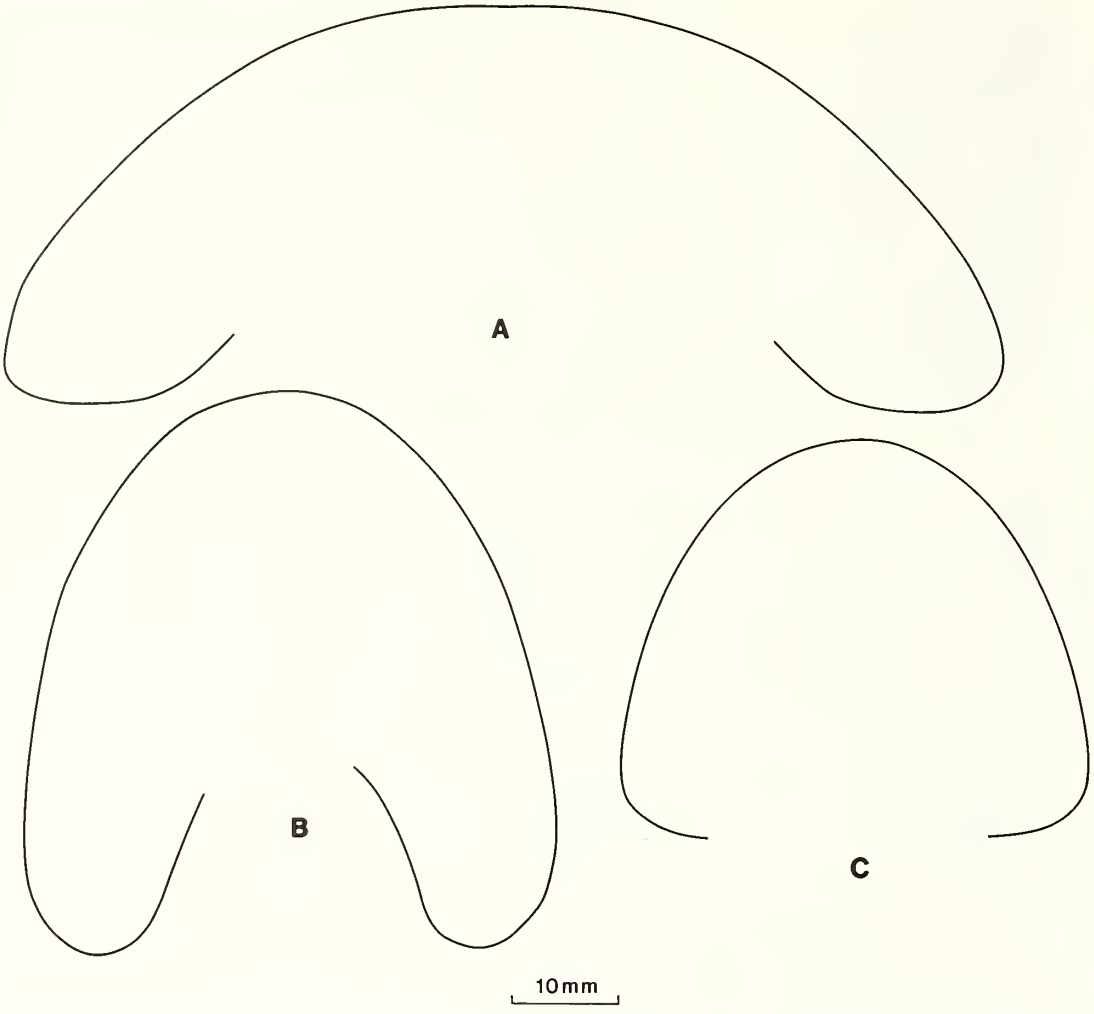
EXPLANATION OF PLATE 5

Figs. 1–8. *Vascoceras proprium* (Reyment, 1954). A series of juveniles showing the range of ornament and whorl section. 1–3, OUM KT380; 4–6, OUM KT369; 7 and 8, OUM KT378.

All specimens are from the Basal Turonian *Pseudaspidoceras flexuosum* Zone fauna of Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas. All figures are × 1.



KENNEDY, WRIGHT and HANCOCK, *Vascoceras*



TEXT-FIG. 8. Whorl sections of *Vascoceras proprium* (Reyment, 1954). A, OUM KT378; B, OUM KT382; C, OUM KT992.

part of the whorl and the venter, with a strong rib behind and in front which, rarely, develop weak to moderate umbilical bullae (Pl. 4, fig. 7). Fold-like ribs may appear after the first constrictions and strengthen to varying degrees. In some specimens they become distinct on the inner part of the flanks by a diameter of 11 or 12 mm, but normally they are strong on the outer and weak on the inner flank (Pl. 4, figs. 10–12). They cross the venter uninterrupted (Pl. 5, fig. 6), with a slight

EXPLANATION OF PLATE 6

Figs. 1–6. *Vascoceras proprium* (Reyment, 1954). 1 and 2, OUM KT387, a juvenile of intermediate inflation; 3 and 4, OUM KT267, a slender, ribbed body-chamber; 5 and 6 OUM KT377, a moderately depressed specimen with body-chamber.

All specimens are from the Lower Turonian *Pseudaspidoceras flexuosum* Zone fauna of Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas. All figures are × 1.

KENNEDY, WRIGHT and HANCOCK *Vascoceras*

TEXT-FIG. 9. *Vascoceras proprium* (Reyment, 1954) the largest of the specimens known from the Basal Turonian *Pseudaspidoceras flexuosum* Zone fauna of Calvert Canyon, OUM KT358; ×0·8.

forward bend. Ribs, where present, generally decline at maturity (Pl. 6, figs. 5 and 6; text-fig. 9), and the adult body-chamber is virtually smooth for the last part.

Some possibly adult specimens are only 75 mm in diameter (Pl. 4, figs. 18 and 19; ?Pl. 6, figs. 3 and 4); others reach 180 mm (text-fig. 9), but our material is inadequate to confirm size dimorphism like that to be documented below in *Fagesia*.

Discussion. The large number of specimens, from a single horizon and locality, at all stages of ontogeny, intergrading in whorl section, nature and persistence of ribbing and presence or absence of umbilical tubercles in early stages are clearly part of a single population. They throw a clear light on the problems of vascoceratine taxonomy at species and to some extent at generic level. It is obvious that descriptions of vascoceratine taxa are of little value unless they cover abundant material and are under tight stratigraphic control. Intermediate specimens in our material match well with the holotype of Reyment's (1954*b*, pl. 5, fig. 1) *Vascoveras proprium*. With this we would synonymize a range of associated forms distinguished by Reyment (1954*b*, 1955) and Barber (1957) (see synonymy).

Powell (1963) described a considerable number of specimens from the horizon of the present material, referring them to *Pachyvascoceras compressum* Barber, 1957 and *P. globosum* Reyment,

1954*b*. These fit in well with our material, and lead to the extreme cadicone variants of our collections (Pl. 5, figs. 7 and 8).

Similar forms are found in several *Vascoceras* faunas, and by themselves are difficult to distinguish. *V. harttii* (Hyatt, 1870 p. 386; 1875, p. 370; White 1887, p. 226, pl. 19, figs. 1 and 2; pl. 20, fig. 3) is a globose cadicone but is distinctly more evolute and has an umbilicus with steeply sloping sides instead of one with overhanging umbilical edges as in the present species. The lectotype of *V. angermanni* Böse, 1920 (p. 217, pl. 16, figs. 2 and 4 only) designated by Chancellor, Reyment, and Tait (1977, p. 92) seems to us indistinguishable from *V. harttii*, whereas specimens described by Chancellor *et al.* (1977) and Chancellor (1982) as *Paravascoceras carteri* (including *V. angermanni* Böse 1920, pl. 16, figs. 1 and 3 (*non* 2 and 4)) seem to be conspecific with our material. The *Neoptychites* aff. *cephalotus* of Böse (1920) also belongs here.

If the material from various localities and horizons is put together it may well be possible to arrange it to show continuous variation in degree of involution, as with whorl shape and ornament. The Calvert Canyon population, however, is uniform in involution throughout all its whorl shapes. Consequently we do not synonymize it with populations that have a significantly different degree of involution.

The Damergou fauna, described by Chudeau (1909), Furon (1935), and Schneegans (1943), includes specimens with a similar range of whorl shapes to those of our material but most individuals are less involute and in the ornamented, compressed individuals the ribbing is much stronger and more persistent. Schöbel (1975) has analysed statistically a large population from this locality and synonymized under *Paravascoceras cauvini* Chudeau, 1909 most of Furon's and Schneegans's species and subspecies of this group. This is probably correct but his population (unpublished study by R. I. Kirby and M. R. Cooper) is strongly dimorphic as regards inflation and also independently dimorphic as regards involution. Since the material was collected from surface scree it is possible that it does not represent part of a single contemporaneous population.

Freund and Raab (1969) distinguished five species of *Paravascoceras* occurring in their *P. cauvini* Zone, of which four were placed, probably correctly, in the synonymy of *cauvini* by Schöbel.

Broggiiceras olssoni Benavides-Cáceres, 1956 and *B. humboldti* Benavides-Cáceres, 1956 (pp. 469–470) appear to resemble *V. cauvini* rather than our material.

Occurrence. Lower Turonian of Texas, northern Mexico, and Nigeria.

Genus FAGESIA Pervinquière, 1907
(= *Plesiovascoceras* Spath, 1925)

Type species. Olcostephanus superstes Kossmat, 1897, p. 26 (133), pl. 6, (17), fig. 1, by original designation.

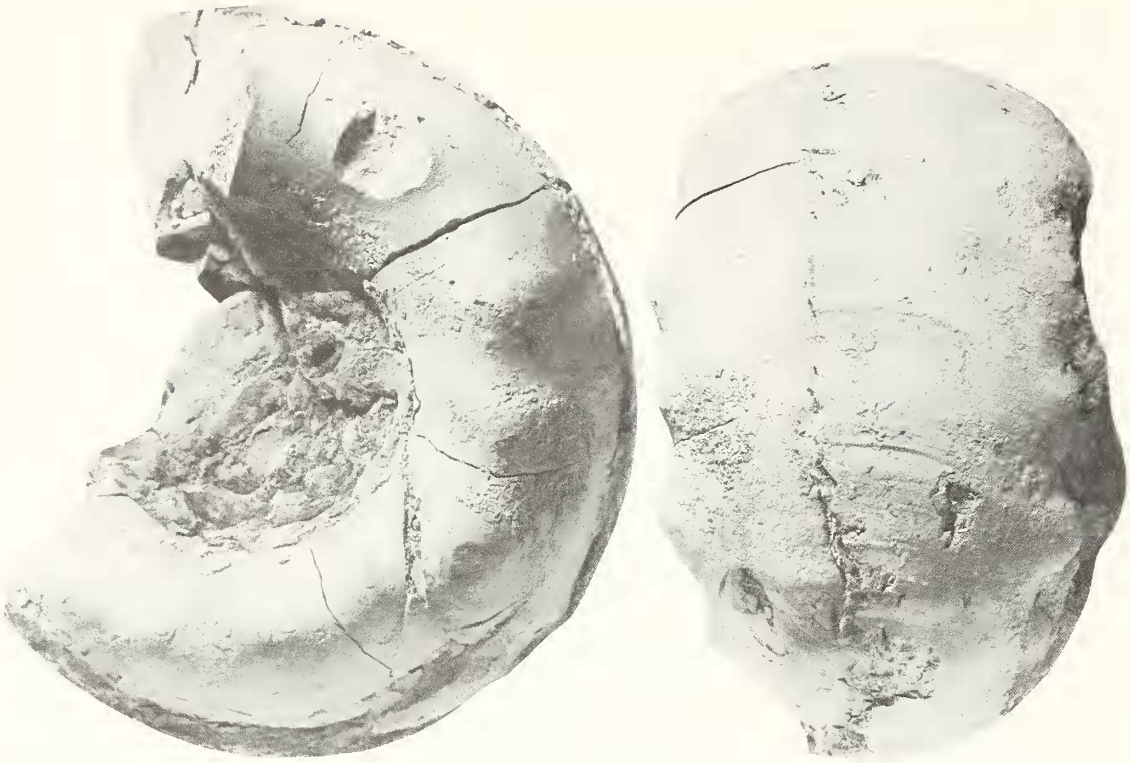
Discussion. See Wright and Kennedy 1981, p. 87.

Fagesia catinus (Mantell, 1822)

Plate 7, figs. 1–13; Plate 8, figs. 1–4, 6–9; text-figs. 2J, K, M, N, 10

1822 *Ammonites catinus* Mantell, p. 198, pl. 22, fig. 10 (*non* fig. 5, attributed in error; = *Ammonites navicularis* Mantell).
1981 *Fagesia catinus* (Mantell, 1822); Wright and Kennedy, p. 88, pl. 26, fig. 2; text-figs. 31–36 (with full synonymy).
1982 *Fagesia haarmanni* Böse; Chancellor, p. 106, figs. 43–48 (with full synonymy).
1982 *Fagesia levis* Renz, p. 78, pl. 22, fig. 20; pl. 23, figs. 1–3; text-figs. 53 and 59*a*, *c*.
1982 *Fagesia* aff. *superstes* (Kossmat); Renz, p. 78, pl. 22, fig. 19; pl. 23, fig. 4; text-fig. 59*b*.
1983 *Fagesia* cf. *thevestensis* Peron; Renz, p. 79, pl. 22, fig. 15.
1982 *Fagesia* aff. *haarmanni* Böse; Renz, p. 79, text-fig. 60.
1982? *Fagesia* sp. indet. Renz, p. 79, pl. 24, fig. 11.

Holotype. By monotypy: BMNH C3379, refigured by Wright and Kennedy 1981, text-fig. 31, from the Middle Chalk of Lewes, Sussex.



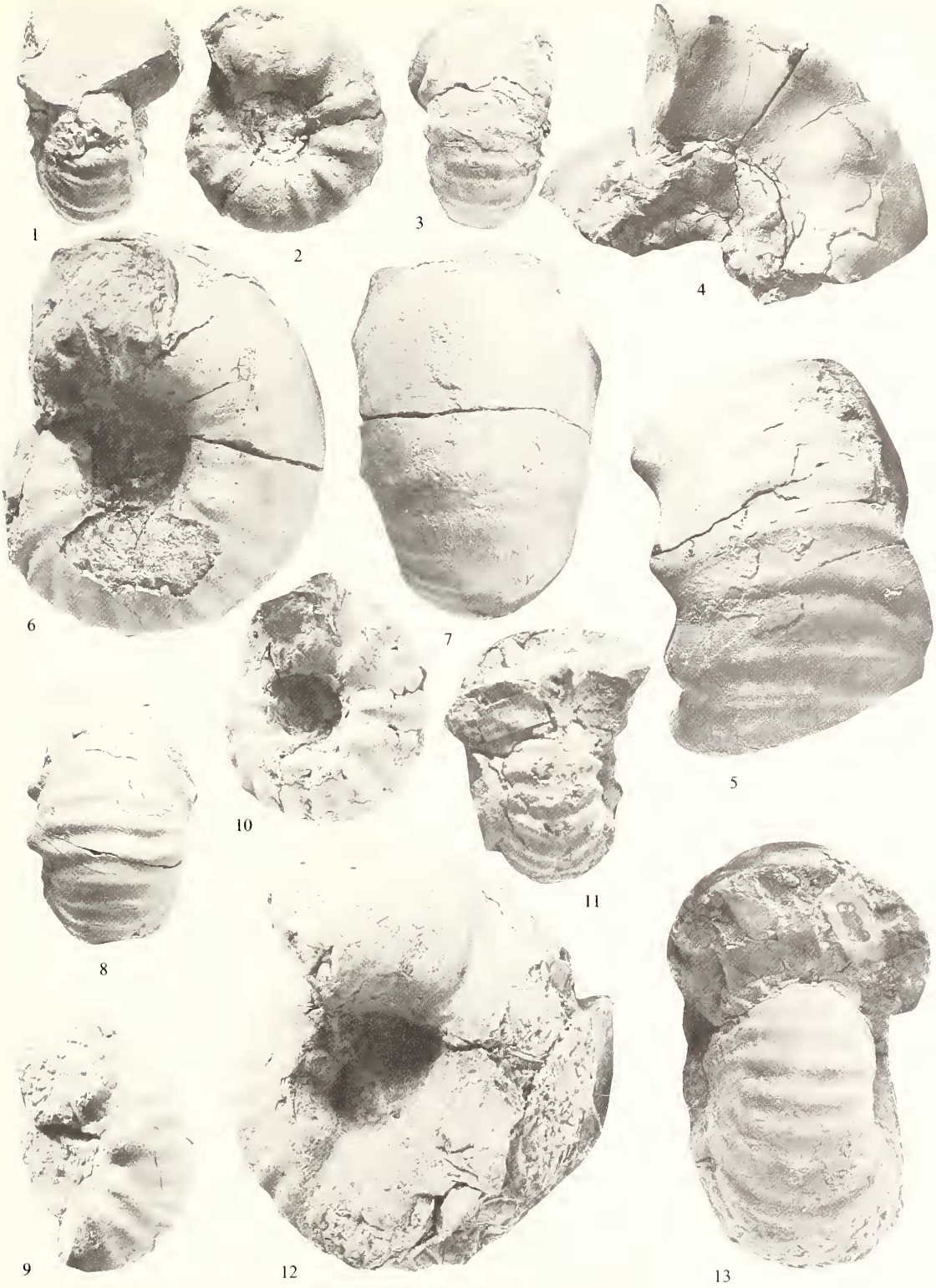
TEXT-FIG. 10. *Fagesia catinus* (Mantell, 1822), juvenile macroconch, OUM KT218, from the Basal Turonian *Pseudaspidoceras flexuosum* Zone of Calvert Canyon; ×0·72.

Description. Inner whorls moderately evolute with a subtrapezoidal to semilunate, depressed whorl section. There are 7–11 prominent umbilical tubercles per whorl, from which generally 1–2, occasionally 3, coarse, prorsiradiate ribs arise, frequently with an intercalatory between nodes. In some juveniles there is a distinct tendency to form very weak ventrolateral bullae (Pl. 7, figs. 8–11). There are about 20–30 ribs per whorl. Beyond 40 mm diameter the ribbing weakens considerably and is eventually lost at greatly varying diameters. In maturity the shell becomes very evolute (umbilicus 50 % of the diameter), with the umbilical wall strongly inclined and the whorl section very depressed coronate. The umbilical tubercles may be retained to maturity or not.

EXPLANATION OF PLATE 7

Fig. 1–13. *Fagesia catinus* (Mantell, 1822). 1–3, OUM KT977, a pathological juvenile with a lateral tubercle on the side figured; 4 and 5, OUM KT246, a strongly ribbed fragment of a cadicone juvenile macroconch; 6 and 7, OUM KT250, a feebly ribbed juvenile; 8 and 9, OUM KT223, a coarsely ribbed juvenile with massive umbilical bullae; 10 and 11, OUM KT248, a very depressed juvenile with incipient ventral bullae; 12 and 13, UTA 20842, the holotype of *F. texana* Adkins, 1933.

The original of figs. 12 and 13 is from an unspecified horizon in the Lower Turonian of the Van Horn Mountains, Culberson County, Texas. The remainder are from the Basal Turonian *Pseudaspidoceras flexuosum* Zone fauna of Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas. All figures are ×1.



KENNEDY, WRIGHT and HANCOCK, *Fagesia*

The most noteworthy variation in the material before us is in the whorl section and the ontogenetic stage at which ribbing finally becomes obsolete. The holotype of *F. texana* Adkins, 1931, loses all its ribbing at about 50 mm diameter (Pl. 7, figs. 12 and 13) and is closely matched by OUM KT250 (Pl. 7, figs. 6 and 7) in which ribbing is also lost at the same diameter. Individuals that lose their ribbing early are also characterized by being somewhat more involute and having a semilunate to reniform whorl section. In addition, the largest individual of this type, OUM KT245 (Pl. 8, figs. 3 and 4), attains an adult diameter of only 100 mm whereas the evolute individuals with sloping umbilical walls and strongly depressed, coronate whorl section attain maturity at much larger diameters (see text-fig. 10 for an incomplete juvenile of this form). This latter form is represented by the holotype of *F. haarmanni* Böse, 1920, '*V.*' *stantoni* Reeside, 1923, and *Ammonites catinus* Mantell, 1822, and frequently attains diameters in excess of 200 mm. The fact that juveniles of the two forms are indistinguishable up to 40 mm diameter, whereafter the shells show somewhat different adult ornament and mature at strikingly different diameters, suggest to us that we are dealing with dimorphs. They may be distinguished as follows:

Microconchs: Adult at diameters up to 100 mm. Shell rather involute (U = 28–35 % of the umbilicus) with ribbing lost at or considerably weakened after about 50 mm diameter. Umbilical tubercles are retained on the body-chamber as rather weak bullae. Whorl section semilunate to reniform, depressed.

Macroconchs: Adult at diameter of the order of 200 mm, with a very evolute shell (umbilicus frequently in excess of 50 % of the diameter). The umbilical walls are strongly inclined, so that the shell becomes cadicone and the umbilical tubercles move to a ventrolateral position. Umbilical tubercles become exaggerated in maturity and are retained onto the adult body-chamber. Whorl section strongly depressed, coronate.

Discussion. F. superstes (Kossmat, 1895) (p. 26 (133), pl. 6 (17), fig. 1) the type species of the genus, differs from *F. catinus* in having more umbilical tubercles per whorl and invariably two ribs arising from each tubercle. Intercalated ribs are lacking.

F. tevesthensis (Peron, 1897) (p. 23, pl. 7(1), figs. 2 and 3) is based upon a juvenile which closely resembles *F. superstes*, from which it differs only in having steeper umbilical walls, with a corresponding change in whorl section. The variation in this respect in the Texas material suggests that *F. tevesthensis* may prove to be a synonym of Kossmat's species. Indeed, this was suggested by Peron (1897, p. 84) who felt that *F. superstes* and *F. tevesthensis* could represent extreme variants of a single species. *A. kotoi* Yabe 1904 (p. 26, pl. 6, figs. 3 and 4) was included in the synonymy of *F. tevesthensis* by Matsumoto (1973).

F. bomba Eck, 1909 (p. 181, text-figs. 1–5), *F. rudra* (Stoliczka, 1865) (p. 122, pl. 60, fig. 1), *F. involuta* Barber 1957 (p. 27, pl. 9, fig. 3; pl. 29, figs. 6 and 7), and *F. pervinquieri* Böse, 1920 (p. 212, pl. 14, fig. 3) are all rather involute, globose species with steep umbilical walls which lack umbilical tubercles from an early growth stage. They show few of the characters of *F. superstes* and are possibly better referred to the genus *Vascoceras*, as suggested by Barber (1957, p. 27).

F. simplex Barber, 1957 (p. 27, pl. 8, fig. 1; pl. 29, figs. 4 and 5) is based upon an immature specimen showing a rather narrow, steep-sided umbilicus and about ten umbilical tubercles per whorl, from which arise broad, weak ribs, frequently in pairs and with occasional intercalatories. It

EXPLANATION OF PLATE 8

Figs. 1–4, 6–9. *Fagesia catinus* (Mantell, 1822). 1 and 2, OUM KT229, a very depressed juvenile; 3 and 4, OUM KT245, the body-chamber of an adult microconch; 6, OUM KT269, a strongly ribbed juvenile; 7–9, OUM KT247, an incomplete slender microconch.

Fig. 5. *Worthoceras* cf. *vermiculus* (Shumard, 1860). OUM KT698.

All specimens are from the Basal Turonian *Pseudaspidoceras flexuosum* Zone fauna of Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas. Fig. 5, × 3; fig. 6, × 2; figs. 1–4, 7–9, × 1.

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KENNEDY, WRIGHT and HANCOCK, *Fagesia*, *Worthoceras*

differs from the Texas material in being weaker and more coarsely ribbed at comparable diameters. The differences are slight.

F. pachydiscoides Spath, 1925 (p. 198) (= *A. catinus* Sharpe (*non* Mantell), 1855, p. 29, pl. 13, fig. 1) differs from *F. catinus* in being still more evolute with gently rounded umbilical shoulders and a reniform whorl section; the rate of increase in whorl width is even less than in the presumed macroconchs of the present species but *F. pachydiscoides* may eventually prove not to be specifically separable.

F. siskiyouensis Anderson, 1931 (p. 125, pl. 17, figs. 2 and 3) was tentatively referred to the Campanian genus *Anapachydiscus* by Matsumoto (1959), whilst *F. klamathensis* Anderson, 1958 (p. 248, pl. 28, fig. 3) was considered a synonym of *Eupachydiscus haradai* (Jimbo, 1894).

F. lenticularis Freund and Raab, 1969 (p. 36, pl. 6, figs. 3–7; pl. 7, figs. 1–3; pl. 8, figs. 1 and 2; text-figs. 7*h–k*, 8*a–i*, 9*a–c*) is based upon crushed material and the variation on which Freund and Raab (1969) based their subspecies *elliptica* and *asymmetrica* are largely, if not entirely, due to post-burial distortion. It is not possible to separate *F. lenticularis asymmetrica* (cf. pl. 6, figs. 3–5) from *F. superstes sphaeroidalis* (Pervinquière) (1907, p. 322, pl. 20, figs. 3 and 4) at a comparable growth stage but, as the holotype of *F. lenticularis* is 380 mm diameter, comparison is difficult. In maturity, *F. lenticularis* is much more involute than *F. catinus* and looses its umbilical tubercles at an early ontogenetic stage.

The authors do not agree with Chancellor's (1982) interpretation of the Mexican *Fagesia*.

Occurrence. Apart from the present occurrences, *F. catinus* is characteristic of a low level in the Turonian of southern England, France, Venezuela, northern Mexico, Texas, Montana, and California. It is also present in the Upper Cenomanian *Neocardioceras juddii* Zone of SW New Mexico.

Genus NEOPTYCHITES Kossmat, 1895

Type species. Ammonites telinga Stoliczka, 1865, p. 125, pl. 62, figs. 1 and 2 (= *A. cephalotus* Courtiller, 1860 p. 248, pl. 2, figs. 1–4), by original designation.

Discussion. See Kennedy and Wright 1979*a* for the most recent discussion of this genus.

Occurrence. Lower and Middle Turonian, France, Spain, Morocco, Algeria, Tunisia, Syria, Israel, Cameroon, Nigeria, Madagascar, southern India, Japan, Texas and the US Western Interior, Mexico, Caribbean, Brazil, Columbia, and Venezuela.

Neoptychites sp.

Plate 9, figs. 5–7, 13–14; text-fig. 2L

Material. OUM KT373, 975, from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Dimensions.

	D	*Wb*	*Wh*	*Wb:Wh*	*U*
OUM KT975	34·2(100)	16·2(47)	17·8(52)	0·91	3·7(11)
OUM KT373	55·3(100)	32·4(59)	28·7(52)	1·12	—(—)

Description. The shell is very involute, with compressed whorls, the greatest breadth being at the umbilical shoulder. The whorl section is subtrigonal; slightly convex flanks converge to a narrow,

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EXPLANATION OF PLATE 9

Figs. 1–4, 8–12, 15–16. *Thomasites adkinsi* (Kummel and Decker, 1954). 1 and 2, OUM KT982; 3 and 4, OUM KT568; 8–9, 12, OUM KT354; 10 and 11, OUM KT356; 15 and 16, OUM KT353.

Figs. 5–7, 13–14. *Neoptychites* sp. 5–7, OUM KT975; 13 and 14, OUM KT313.

All specimens are from the Basal Turonian *Pseudaspidoceras flexuosum* Zone fauna of Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas. Figs. 1–4, ×2; figs. 5–16, ×1.

KENNEDY, WRIGHT and HANCOCK, *Thomasites*, *Neoptychites*

evenly rounded venter. Faint fold-like ribs are visible on the ventral region at the smallest diameters visible.

Neither specimen shows the sutures.

Discussion. Pervinquière (1907) and Kennedy and Wright (1979*a*) amongst others have commented on the variability in ornament and proportions of juvenile *Neoptychites*. The present specimens probably belong to the *cephalotus* group but are best left in open nomenclature.

Subfamily PSEUDOTISSOTIINAE Hyatt, 1903
Genus WRIGHTOCERAS Reyment, 1954
(? = *Imlayiceras* Leanza, 1967)

Type species. Bauchioceras (*Wrightoceras*) *wallsi* Reyment, 1954*a*, p. 160, pl. 2, fig. 4, pl. 3, fig. 3, by original designation.

Discussion. See Hirano (1983) for a review of this genus.

Wrightoceras munieri (Pervinquière, 1907)

Plate 10, figs. 9–11; text-fig. 2E

1907 *Hoplitoides munieri* Pervinquière, p. 217, pl. 10, figs. 1 and 2; text-fig. 83.
1920 *Hoplitoides* aff. *mirabilis* Pervinquière; Böse, p. 225, pl. 19, figs. 1–3.
non 1954 '*Hoplitoides*' cf. *munieri* Pervinquière; Kummel and Decker, p. 317, pl. 33, figs. 1 and 2; text-figs. 7*a*, 10 (= *Herrickiceras costatum* (Herrick and Johnson, 1900)).
1956 *Hoplitoides inca* Benavides-Cáceres, p. 475, pl. 63, figs. 6–11; text-fig. 54.
?1967 *Proplacenticeras zeharense* Collignon, p. 33, pl. 18, figs. 5 and 6 (?7–9).
?1967 *Imlayiceras washbourni* Leanza, p. 198, pl. 4, figs. 1–4; pl. 6, figs. 1, 4–6.
1975 *Wrightoceras munieri* (Pervinquière); Wiedmann, p. 144, pl. 2, fig. 2.
1979 *Imlayiceras* ? *ralphimlayi* Etayo-Serna, p. 88, pl. 13, fig. 3; text-fig. 8*a*.
1982 *Wrightoceras* cf. *munieri* (Pervinquière); Chancellor, p. 119, figs. 24, 60–63.
1982 *Hoplitoides munieri* Pervinquière; Renz, p. 100, pl. 31, figs. 3–6, 11.

Holotype. The original of Pervinquière 1907, p. 217, pl. 10, fig. 2, from the Lower Turonian of Draa el Miaad, Tunisia.

Material. OUM KT396–399, 531, 534, 556, 665, 706, 788, from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Dimensions

	D	*Wb*	*Wh*	*Wb:Wh*	*U*
OUM KT396	85·5(100)	19·7(23·0)	47·4(55·4)	41·6	9·2(10·8)

Description. Very compressed, involute, with narrow sulcate-bicarinate venter.

Discussion. Our material is largely fragmentary, but obviously belongs to Pervinquière's species, the types of which are before us. *Imlayiceras washbournei* Leanza, 1967 (p. 198, pl. 4, figs. 1–4; pl. 6, figs. 1, 4–6) closely resembles the present species but has feeble umbilical bullae on the inner whorls, as shown in text-fig. 11A–D. It is regarded as a possible synonym.

The *Hoplitoides* cf. *munieri* of Kummel and Decker (1954, p. 317, pl. 33, figs. 1 and 2; text-figs.

EXPLANATION OF PLATE 10

Figs. 1–8. *Allocrioceras larvatum* (Conrad, 1855). 1, OUM KT315; 2, OUM KT314; 3, OUM KT659; 4, OUM KT736; 5, OUM KT736*a*; 6 and 7, OUM KT336; 8, OUM KT312.
Figs. 9–11. *Wrightoceras munieri* (Pervinquière, 1907). 9 and 10, OUM KT396; 11, OUM KT399.
Figs. 12 and 13. *Allocrioceras dentonense* Moreman, 1942. OUM KT424.

All specimens are from the Basal Turonian *Pseudaspidoceras flexuosum* Zone fauna of Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas. Figs. 1–8, 12, 13, × 2; figs. 9–11, × 1.

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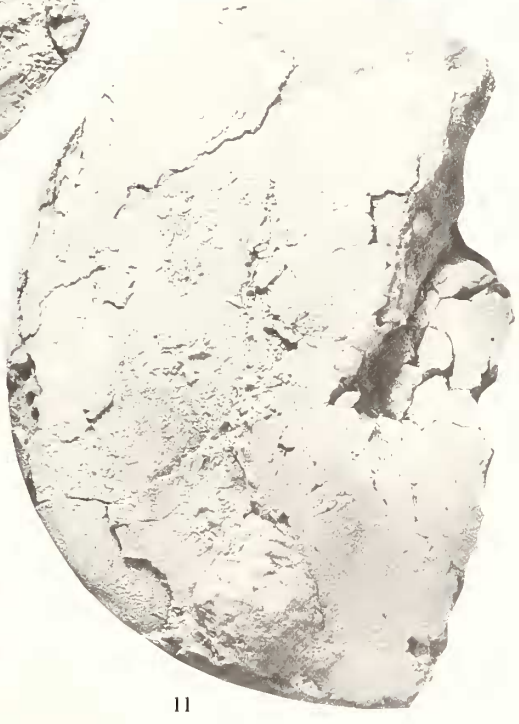
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KENNEDY, WRIGHT and HANCOCK, *Allocrioceras*, *Wrightoceras*

TEXT-FIG. 11. *Imlayiceras washbourni* Leanza, 1967. The holotype, USNM 132.556, from the Lower Turonian of Ubate, Colombia; × 1.

7*a* and 10) is referred by Cobban and Hook (1980, p. 22) to *Herrickiceras* Cobban and Hook, 1980, a homoeomorphic Middle Turonian coilopoceratid.

A further possible synonym of the present species is *Proplacenticeras zeharense* Collignon, 1967 (p. 33, pl. 18, figs. 5–9) from the Turonian of Tarfaya, Morocco, although in the absence of sutures this is not fully proven, while one of the paratypes (pl. 18, fig. 7) shows a rounding venter.

Hirano (1983) discusses the Nigerian *Wrightoceras*, none of which closely resemble the present species.

Occurrence. Lower Turonian of Texas and northern Mexico, Venezuela, Peru, ?Colombia, Spain, Tunisia, and ?Morocco.

Genus THOMASITES Pervinquière, 1907
(= *Gombeoceras* Reyment, 1954*a*; *Koulabiceras* Atabekjan, 1966; *Ferganites* Stankievich and Pojarkova, 1969)

Type species. Pachydiscus rollandi Peron, 1890, p. 25, pl. 17, figs. 1–3, by original designation.

Discussion. See Wright and Kennedy 1981, p. 98 for a review of the genus and its synonyms.

Thomasites adkinsi (Kummel and Decker, 1954)

Plate 9, figs. 1–4, 8–12, 15–16; text-fig. 21

1954 '*Hoplitoides*' *adkinsi* Kummel and Decker, p. 316, pl. 32, fig. 6; pl. 33, fig. 3; text-figs. 7*b* and 8.
1957 *Pseudotissotia* (*Bauchioceras*) *adkinsi* (Kummel and Decker); Barber, p. 47.
1982 *Pseudotissotia adkinsi* (Kummel and Decker); Chancellor, p. 116, figs. 21, 66–69 (with synonymy).

Holotype. The original of Kummel and Decker 1954, pl. 32, fig. 6, pl. 33, fig. 3, from the Turonian of Piedra de Lumbre, Coahuila, Mexico.

Material. Six specimens, OUM KT353–356, 418, 427, from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Dimensions

	D	*Wb*	*Wh*	*Wb:Wh*	*U*
OUM KT354	61·8(100)	26·3(42·6)	30·1(48·7)	0·87	10·0(16·2)

Description. 0–25 mm diameter: The earliest growth stages are involute (umbilicus 16 % of the diameter), with steep, slightly overhanging umbilical walls and an abruptly rounded umbilical shoulder. The flattened flanks converge slightly towards the somewhat flattened, trituberculate venter. On the adoral quarter of the outer whorl there are two prominent umbilical bullae from which arise weak, slightly prorsiradiate, single ribs. The outer half of the flanks is ornamented with weak ribs corresponding to the rows of tubercles across the venter.

25–45 mm diameter: This growth stage is represented by several fragments (Pl. 9, figs. 1–4, 10–11) which show the whorls to be very compressed, much higher than wide, with flattened flanks. At this growth stage the venter is weakly fastigiate, with three prominent rows of weakly clavate tubercles; the siphonal row already forms a weak keel.

45–65 mm diameter: This growth stage is represented by the best preserved specimen, OUM KT354 (Pl. 9, figs. 8–9, 12). The shell is rather involute (umbilicus 16 % of the diameter), compressed, with an elliptical whorl section. The umbilicus is narrow and deep, with vertical umbilical walls and an abruptly rounded umbilical shoulder. The broad, slightly convex flanks converge towards the narrow, truncated venter and maximum width is just above the umbilical shoulder. The venter is tricarinate-bisulcate although the keels are distinctly nodate. Save for growth striae, the flanks lack ornament.

60 mm diameter: A single fragment, retaining shell, OUM KT353 (Pl. 9, figs. 15 and 16) shows the late growth stages of this species. The flanks are still flattened and converge towards the venter which is now evenly rounded. Only the siphonal keel persists at this growth stage although the

ventrolateral shoulders are again marked by very weak nodes which are all that are left of the tricarinate middle growth stages. Both the flanks and the venter are crossed by rather prominent growth striae.

Discussion. Although referred by all previous authors to *Pseudotissotia* (and its synonyms), a genus characterized by a tricarinate venter throughout most of its ontogeny, we would refer the present species to *Thomasites* for the following reasons: (i) the trituberculate, fastigiate venter is retained to advanced growth stages; (ii) the tricarinate stage is only developed for a short period during ontogeny; and (iii) the ventrolateral keels are still weakly nodate on the body-chamber.

T. adkinsi is intermediate between early *Thomasites* (i.e. '*Gombeoceras*') and early *Pseudotissotia* (i.e. '*Bauchioceras*'), but is best included in the former. The boundaries, if any, between *T. rollandi* (Peron, 1890), *T. gongilensis* (Woods, 1911) and *T. adkinsi* can only be decided on the basis of large populations of well-preserved specimens.

Occurrence. Lower Turonian of west Texas and northern Mexico.

Suborder ANCYLOCERATINA Wiedmann, 1966
Superfamily TURRILITACEAE Gill, 1871
Family ANISOCERATIDAE Hyatt, 1900
Genus ALLOCRIOCERAS Spath, 1926

Type species. By original designation: *Crioceras ellipticum* Woods, 1896, p. 84 (*non* Mantell), renamed *Allocrioceras woodsi* Spath, 1939 p. 598, = *Hamites angustus* J. de C. Sowerby 1850, p. 346, pl. 29, fig. 12.

Occurrence. Uppermost Cenomanian to Lower Coniacian. Species are known from western Europe, Nigeria, Zululand, Japan, the US western interior, Texas, and Mexico.

Allocrioceras dentonense Moreman, 1942

Plate 10, figs. 12 and 13

1942 *Allocrioceras dentonense* Moreman, p. 209, pl. 34, fig. 4; text-fig. 2H.
1963 *Allocrioceras dentonense* Moreman; Swensen, p. 78, pl. 1, figs. 7 and 8; pl. 3, fig. 3.
1965 *Allocrioceras dentonense* Moreman; Clark, p. 32, pl. 1, figs. 7 and 8; pl. 5, fig. 3; text-fig. 12*b*.

Type. The holotype by monotypy is UTA 19808, from the Britton Formation east of Lewisville, Texas.

Material. OUM KT424, from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Description. The fragment is part of a loosely coiled, planispiral shell, with a compressed, rectangular whorl section. The broad, flattened flanks are ornamented with four rather robust, slightly prorsiradiate ribs in a distance equal to the whorl height. All ribs terminate in small, pointed ventrolateral tubercles which are joined across the venter by a pair of weakly looped ribs.

Discussion. The present fragment closely matches Moreman's holotype (see Clark 1965, pl. 5, fig. 3) in whorl section and nature of the ribbing. It is not known, however, whether Moreman's species shows the looped ribbing across the venter evident in the fragment before us. However, Moreman (1942) does note that in his species the ribs are 'flat' across the venter; such flattening is perhaps comparable to incipient looping.

A. annulatum (Shumard, 1860) (p. 595) has an almost circular whorl section and oblique ribbing across the venter, characters which readily separate it from the present fragment. Common features, however, are the looped ribs across the venter and the presence of ventrolateral tubercles on every rib. Cobban and Scott (1972) have included *A. pariense* (White, 1887) (p. 203, pl. 19, fig. 2) in the synonymy of *A. annulatum*.

In *A. larvatum* (Conrad, 1855) (p. 265) the whorl section is ovate, and only slightly higher than wide, and only every alternate rib bears ventrolateral tubercles.

Occurrence. Upper Cenomanian of central Texas; basal Turonian of west Texas.

Allocrioceras larvatum (Conrad, 1855)

Plate 10, figs. 1–8

1855 *Hamites larvatus* Conrad, p. 265.
1857 *Hamites larvatus* Conrad; Conrad in Emory, pl. 21, fig. 8.
1928 *Hamites larvatus* Conrad; Adkins, p. 209.
1933 *Allocrioceras larvatum* (Conrad); Adkins, p. 439.
1942 *Allocrioceras larvatum* (Conrad); Moreman, p. 208, text-fig. 2*i*.
1963 *Allocrioceras larvatum* (Conrad); Swensen, p. 80.
1963 *Allocrioceras* sp. Powell, p. 322, pl. 31, fig. 18.
1965 *Allocrioceras larvatum* (Conrad); Clark, p. 32.

Type. Holotype, by monotypy, no. 4790 in the collections of the Philadelphia Academy of Sciences, from the Upper Cenomanian Britton Formation of Dallas County, Texas.

Material. More than 150 specimens in the Oxford University Museum Collections from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Description. This is a rather common species in the Calvert Canyon fauna, and the ontogenetic development can be deduced from various fragments.

The initial coiling is in a loose planispire (Pl. 10, figs. 3 and 4). Up to a whorl height of 1 mm, the shell is very weakly ornamented, almost smooth, whereafter there are slightly prorsiradiate ribs, 4·5 in a distance equal to the whorl height. They are very weak across the dorsum, but strengthen ventrally. At this stage there is no sign of ventrolateral tubercles. Weak ventrolateral tubercles appear on alternate ribs at a whorl height slightly in excess of 2 mm. At this growth stage the whorl section is compressed oval.

At larger growth stages (Pl. 10, fig. 2) the whorl section is elliptical, compressed, and the flanks show signs of flattening. There are six prorsiradiate ribs in a distance equal to the whorl height across the flanks, of which three bear small pointed ventrolateral tubercles. There is usually only one, rarely two non-tuberculate ribs between the tuberculate ribs, and they tend to be somewhat finer than the tuberculate ones. The ventrolateral tubercles are joined transversely across the venter by a broad, flattened rib which may show incipient looping.

A still larger growth stage of this species is shown by OUM KT315 (Pl. 10, fig. 1). This fragment clearly shows the tendency for the shell to become higher whorled and more compressed with growth (see also Pl. 10, fig. 8). This in turn results in an increasing rib density, with now seven ribs in a distance equal to the whorl height. This fragment also shows one instance of two non-tuberculate ribs between adjacent tuberculate ones.

The most significant variation in the material before us is in the increase in whorl height which means that the later growth stages are more densely ribbed, with a more compressed whorl section than is seen in juveniles. Add to this the absence of ventrolateral tubercles on the earliest whorls, and the two growth stages could readily be separated into different genera: *Hamites* and *Allocrioceras*.

Discussion. The present species differs from *A. dentonense* in being more densely ribbed at comparable growth stages and generally with tubercles on every alternate rib. *A. annulatum* has an almost circular whorl section at large growth stages and also has tubercles on every rib.

Occurrence. Upper Cenomian and basal Turonian. West and central Texas and northern Mexico.

Family BACULITIDAE Gill, 1871

Genus SCIPONOCERAS Hyatt, 1894

(= *Cyrtochilus* Meek, 1876 (*non* Jakowlew, 1875); *Cyrtochilella* Strand, 1929)

Type species. By original designation: *Hamites baculoides* Mantell, 1822, p. 123, pl. 23, figs. 6 and 7.

Discussion. See Wright and Kennedy 1981, p. 112 for recent comments on this genus.

Sciponoceras sp.

Plate 2, figs. 5–7

Material. OUM KT334 and 652, from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

Description. The shell is slowly expanding with a compressed whorl section (the whorl breadth to height ratio is 0·62), broadly rounded flanks, and narrowly rounded dorsum and venter. There is a single concave constriction on one specimen. The sutures are not exposed.

Remarks. The presence of a constriction confirms this as a *Sciponoceras* rather than *Baculites*. It is specifically indeterminate.

Superfamily SCAPHITACEAE Gill, 1871
Family SCAPHITIDAE Gill, 1871
Subfamily OTOSCAPHITINAE Wright, 1953
Genus WORTHOCERAS Adkins, 1928

Type species. Macroscaphites platydorsatus Scott, 1924, p. 18, pl. 5, pl. 6, pl. 9, fig. 6, by original designation.

Diagnosis. Small, strongly dimorphic. Evolute spire followed by moderately to very long straight shaft and terminal hook; aperture, where known, simple in macroconchs and with long, straight lappets in microconchs. Shell surface smooth or with very feeble ribs. Sutures simple, quadrilobate, with bifid saddles and trifid to bifid lobes.

Occurrence. Upper Albian to Upper Turonian of western and central Europe, New Zealand, Texas, and the US Western Interior.

Worthoceras cf. *vermiculus* (Shumard, 1860)

Plate 8, fig. 5

compare:
1860 *Scaphites vermiculus* Shumard, p. 594.
1965 *Worthoceras vermiculum* (Shumard); Clark, p. 62, pl. 4, figs. 9–11.
1972 *Worthoceras vermiculum* (Shumard); Cobban and Scott, p. 43 (with synonymy).

Type. Shumard's original material appears lost. Moreman (1942) established a neotype, UTA 19827; it is from the Upper Cenomian Britton Formation 0·5 miles east of the Britton–Midlothian highway, 2·7 miles south of Britton, Texas.

Material. One distorted near complete specimen and two spires on OUM KT698, from Bed B of the Ojinaga Formation, Calvert Canyon, Hudspeth County, Texas.

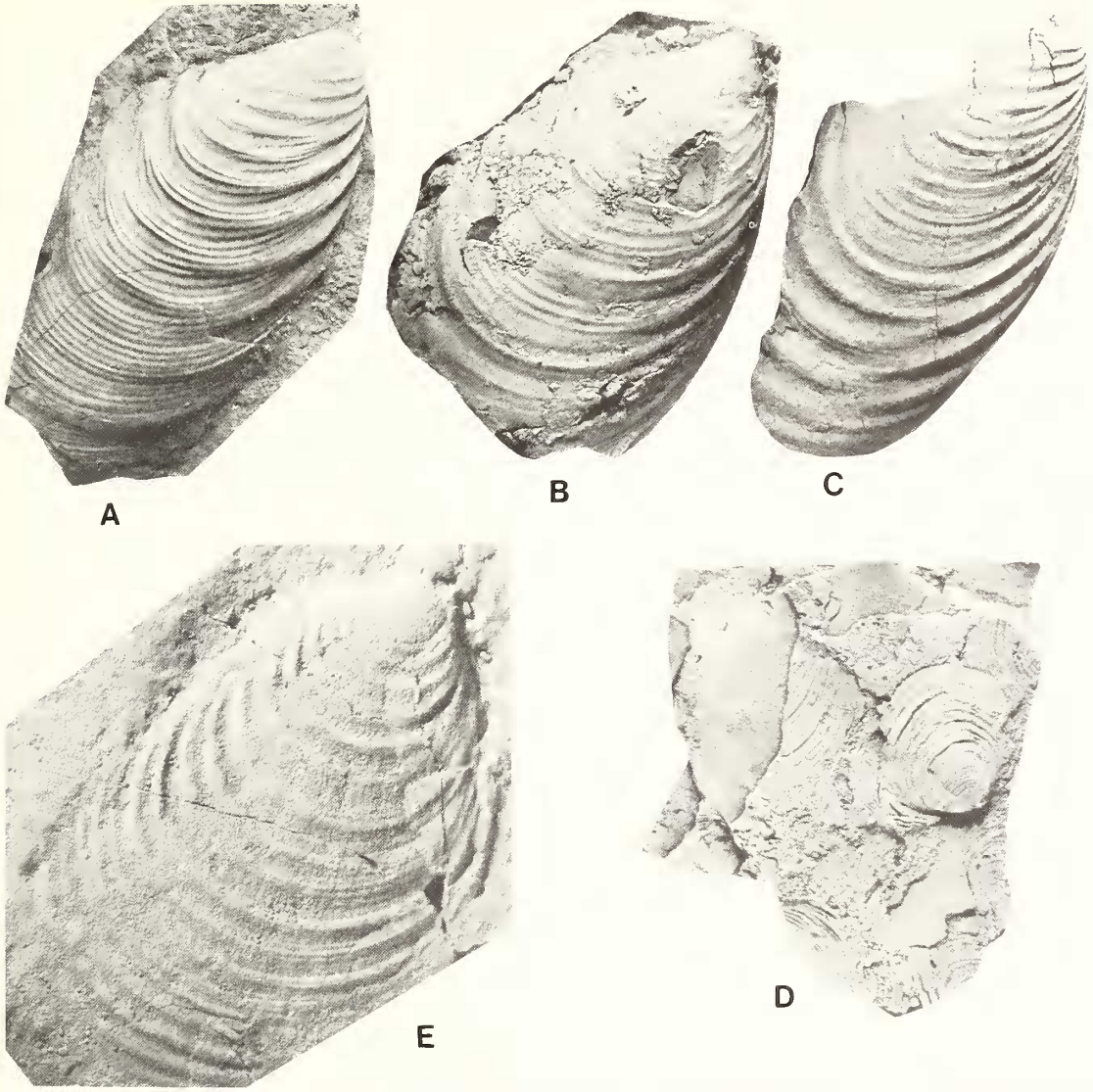
Description. These tiny specimens add nothing to previous descriptions, and preservation precludes confident determination.

Remarks. The trivial name of this form should be *vermiculus* (*Latin*, little worm) since it is a noun in apposition to the genus.

Occurrence. Upper Cenomian and Lower Turonian of central and west Texas, Colorado, Kansas, and Montana.

DISCUSSION

The fauna of the *Pseudaspidoceras flexuosum* Zone in west Texas is characterised by abundant *Quitmaniceras reaseri*, *P. flexuosum*, *Vascoceras proprium*, *Fagesia catinus*, and *A. larvatum*; less common are *Mammites powelli*, *Neoptychites* sp., *Wrightoceras munieri*, *T. adkinsi*, *A. dentonense*, *Sciponoceras* sp., and *Worthoceras* cf. *vermiculus*. Inoceramid bivalves are abundant, with many *Mytiloides* (text-fig. 12A–C). The unpublished work of Dr W. A. Cobban (letter of 6 March 1985)



TEXT-FIG. 12. A–C, *Mytiloides columbianus* (Heinz, 1935), the *M. opalensis* of authors *non* Böse and *M. plicatus* (d'Orbigny) that typifies the Basal Turonian. × 1. A, OUM KT488; B, OUM KT510; C, OUM KT470; all are from the Basal Turonian *Pseudaspidoceras flexuosum* Zone of Calvert Canyon, Texas. D shows the syntypes of *Inoceramus plicatus*, no. 5504 in the D'Orbigny Collection, Museum d'Histoire Naturelle, Paris, from 'Santa Fe du Bogota, Nouvelle Grenade'. E, a cast of the original of *M. opalensis* Böse, 1923, p. 184, pl. 13, figs. 2 and 3, from Opal, Zacatecas, Mexico.

shows that this species, the *M. opalensis* of Seitz and other authors, also referred to *M. plicatus* (d'Orbigny, 1842), the surviving syntypes of which are shown as text-fig. 12D, should be called *M. columbianus* (Heinz, 1935). True *M. opalensis* (Böse 1923, pl. 13, figs. 2 and 3 only) (text-fig. 12E) is a younger Turonian species.

At Calvert Canyon this assemblage is found in stratigraphic isolation, but, as noted in the introduction to this paper, it occurs elsewhere in west Texas (e.g. Chispa Summit) and New Mexico (Cobban 1984), immediately above a distinctive assemblage of the *Neocardioceras juddii* Zone.

regarded as Upper Cenomanian. The *juddii* Zone fauna in this region includes *N. juddii* (Barrois and Guerne, 1878), *P. pseudonodosoides* (Choffat, 1898) (text-fig. 6A, B), *Kamerunoceras*, and *Vascoceras* species. We take the base of the *flexuosum* Zone as the base of the Turonian stage for reasons discussed fully elsewhere (Hancock 1984; Kennedy 1984; see also Cobban 1984; Birkelund *et al.* 1984). Here we discuss the correlation of this boundary with some of the better known boundary successions in both Boreal and Tethyan Realms.

United States Western Interior

The best documented Cenomanian–Turonian boundary section is Rock Canyon, Pueblo, Colorado (Cobban and Scott 1972), and the boundary is discussed in detail by Kauffman *et al.* (1978) who show the intervention of an anoxic interval around this level. No *juddii* Zone forms are recorded from the Pueblo area, but the boundary lies above Bed 77 and below Bed 97, and possibly between Beds 79 and 86 of the published section (Cobban and Scott 1972, pp. 23–24). However, fossils of the *N. juddii* and *P. flexuosum* Zones do occur in the western interior (Cobban 1983, 1984), while the presence of an ammonite and inoceramid association typical of the *flexuosum* Zone as far north as Montana (Reeside 1923) shows that there is no biogeographic hindrance to recognizing this boundary throughout the region.

Western Europe

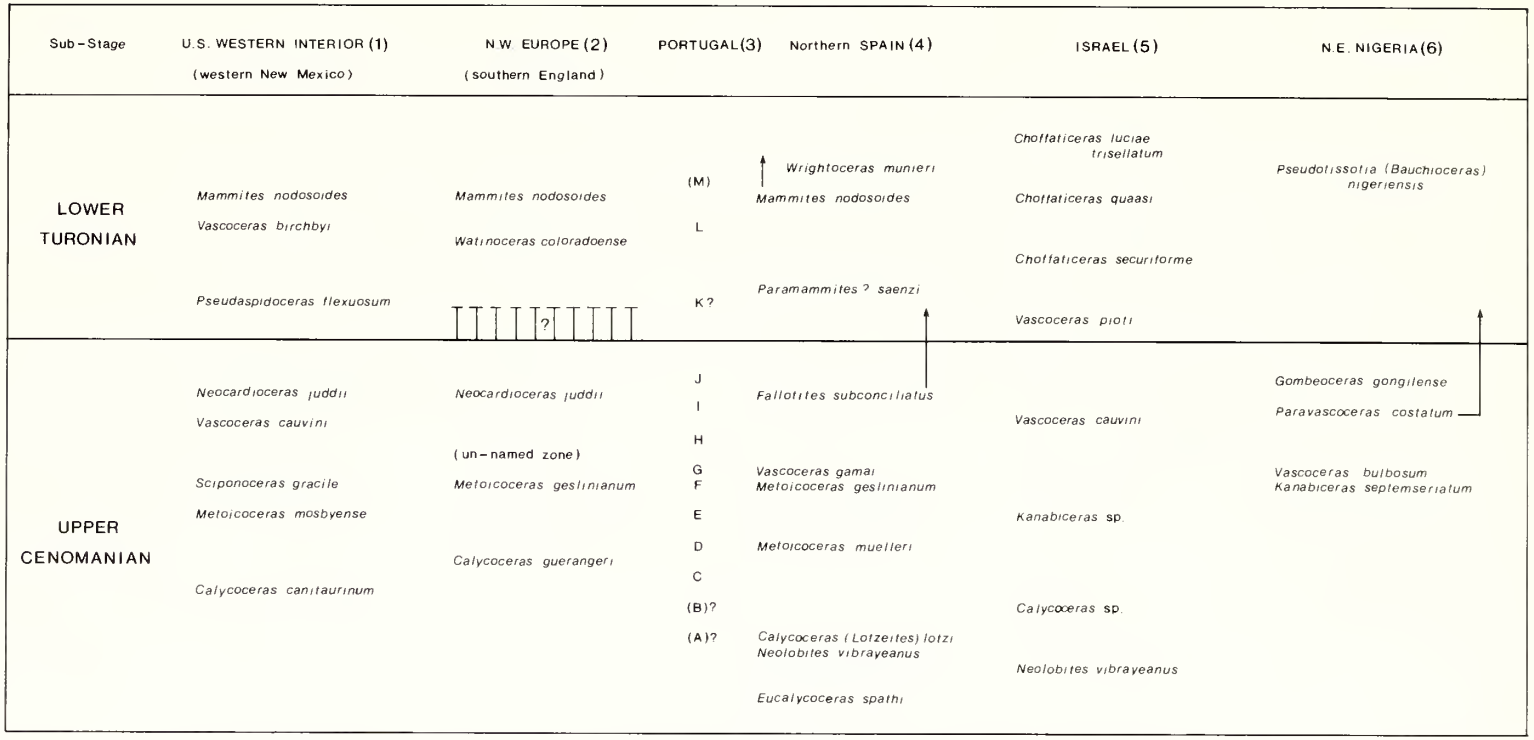
The proposed correlation is shown in text-fig. 13. The wide occurrence of *N. juddii* is now well known (Wright and Kennedy 1981; Amedro *et al.* 1984) and we have new records from Haute Normandie, Aube, and West Germany. It is unfortunate that around this level there is either sedimentary condensation or anoxic black shale, and interpretation of many sections is difficult. In southern England the condensed successions of the Beer district (Wright and Kennedy 1981; Jarvis and Woodroof 1984) show the *juddii* Zone overlain by what has been termed a *Watinoceras coloradoense* Zone fauna of the Lower Turonian with diverse *Watinoceras* species, none of which occurs in the *flexuosum* Zone in south-west Texas. The ammonite assemblage is nevertheless accompanied by diverse inoceramids, including numerous *Mytiloides* conspecific with the form we refer to as *M. columbianus*. The *coloradoense* Zone is in turn overlain by the *Mammites nodosoides* Zone that contains elements in common with the *nodosoides* Zone in the interior of the United States, so that it is likely that the *coloradoense* Zone of western Europe corresponds to parts or all of the *birchbyi* and *flexuosum* Zones of the USA.

P. flexuosum is known from near Dresden in the German Democratic Republic (the '*M. footeanus* Stol. spec.' of Petrascheck 1902 p. 14, pl. 9, fig. 1), but is, unfortunately, imprecisely dated with respect to other ammonites in this region.

Iberian Peninsula

Berthou and Lauverjat and their collaborators have described the sequence in the *Vascoceras*-dominated successions of the Portugese littoral in a series of papers, summarized by Berthou (1984). Part of the key to the correlation shown in text-fig. 13 is the extension of *P. pseudonodosoides* up to Division J of the succession of Choffat (1898); this is an exclusively *juddii* Zone species in North America. It is accompanied by the type material of *Spathites subconciliatus* (Choffat, 1898) which thus appears in Portugal, as in England, as low as the *juddii* Zone. The upper limit of *S. subconciliatus* is less certain. In Portugal it does not range above the *juddii* Zone Level J (Berthou 1984), but in northern Spain it is recorded by Wiedmann (1978) from the same division as *Mytiloides opalensis* (Seitz *non* Böse, e.g. *M. columbianus*), the typically *flexuosum* Zone inoceramid. In western Aquitaine it probably occurs still higher, the variable *Spathites* populations of the *Mammites nodosoides* Zone yielding individuals close to the types of *subconciliatus*. In England there is a possible example from the *coloradoense* Zone in Devon (Wright and Kennedy 1981). It would seem that *S. subconciliatus* is a species with a total range through several zones.

The lowest definite Turonian assemblage in Portugal is found in Level L of Choffat. None of the species quoted by Berthou has yet been found in Texas and no direct correlation is at present possible.



TEXT-FIG. 13. Inter-regional correlation of the Cenomanian–Turonian boundary. (1) After Cobban and Hook 1983, table 1, and Cobban 1984; (2) after Wright and Kennedy 1981 and Wright *et al.* 1984; (3) after Choffat 1898 and Berthou 1984; (4) after Wiedmann 1979; (5) after Freund and Raab 1969 and Lewy *et al.* 1984; (6) after Wozny and Kogbe 1983. The correlation is largely ours. The names have been left as quoted by the authors; our own opinion is that: *Fallotites subconciliatus* = *Spathites* (*Jeanrogericeras*) *subconciliatus*; *Gombeoceras gongilense* = *Thomasites gongilensis*; *Paravascoceras costatum* = *Vascoceras proprium*.

Israel

The sequences in the Negev (Freund and Raab 1969; text-fig. 13) provide a standard for much of the Middle East and the Sahel. Lewy *et al.* (1984) have recorded *Metoicoceras geslinianum* of the Upper Cenomanian from the *Kanabiceras* Zone of Freund and Raab together with early representatives of *V. cauvini*, while the *cauvini* Zone of Freud and Raab yields *P. pseudonodosoides* (text-fig. 6E, F) showing it to be equivalent to the *juddii* Zone. There are no common elements between the *flexuosum* Zone faunas discussed here and those of the Israeli *pioti* Zone, but our unpublished work in central Tunisia shows that *V. durandi* (Peron, 1890), a species known from the *pioti* Zone, appears above the correlative of the *juddii* Zone in association with fragmentary *P.* cf. *flexuosum*.

Nigeria

The important vascoceratid-dominated faunas of this country provide a key to wider correlation across the trans-Saharan seaway (see Dufavre *et al.* 1984). These faunas have been discussed by Reyment (1954*a*, *b*, 1955) and Barber (1957), whilst Wozny and Kogbe (1983) have reviewed key sections in the Upper Benue Basin. *P. flexuosum* occurs in north-east Nigeria (the *P. paganum* Reyment of Barber (1957, p. 9) in part belongs to this species), while *V. proprium*, the commonest ammonite in the *flexuosum* Zone in west Texas, was first described from Bauchi Province.

Actual correlations are more difficult than might be hoped, in spite of detailed stratigraphy by Barber (1957) and Wozny and Kogbe (1983). *Pseudaspidoceras* has not been recorded from an exact level. *V. proprium* (as *Paravascoceras costatum costatum* and *P. c. tectiforme* by Wozny and Kogbe and as *V. globosum* in both papers) occurs in the *costatum* Zone according to Wozny and Kogbe but only in the upper half of the Zone according to Barber. This would place the base of the Turonian at the base or in the middle of the Nigerian *costatum* Zone.

On the other hand the *costatum* Zone also contains:

(i) *Metengonoceras dumbli* (Cragin 1893) which in northern France extends to the upper part of the *geslinianum* Zone and does not range above the Cenomanian in north Texas, the region where it is best known (Hancock and Kennedy 1981).

(ii) *T. gongilensis* including subsp. *tectiformis* and *lautus* that in Devon occurs below and in the *juddii* Zone, i.e. distinctly below the summit of the Cenomanian.

(iii) *Nigericeras*, a genus often listed as 'Lower Turonian', although all the stratigraphically controlled records are within the Cenomanian, e.g. below the *juddii* Zone in Devon, from the *Kanabiceras* Zone in Israel, and the Upper Cenomanian of Angola (Wright and Kennedy 1981).

It may well turn out that the finer divisions of Nigeria cannot be recognized internationally but, provisionally, we would place the base of the Turonian as somewhere within the *costatum* Zone of Barber, i.e. within Bed 9 of the Pindiga section (Barber 1957, table 3).

Other regions

As yet it is not really possible to make detailed comparisons with other regions famous for their mid-Cretaceous ammonites.

In Japan there are too few ammonites from critical levels to allow useful discussion (Matsumoto 1977, 1982).

In Soviet central Asia there are almost no ammonite species in common with the other regions discussed here (Pojarkova 1984), further emphasized since Wright and Kennedy (1981) have maintained that *T. koulabicum* (Kler), the most common ammonite in Pojarkova's Lower Turonian, is distinct from all the Nigerian forms.

In southern India there are several zones missing in the succession close to the Cenomanian–Turonian boundary according to Ayyasami and Banerji (1984).

The rich Madagascan assemblages suffer from inadequate stratigraphic control (Besairie and Collignon 1972). We have not yet made a full study of our material from Tunisia.

Acknowledgements. We thank Don Reaser of Arlington, Texas, for guiding us in the Quitman Mountains, Ray Parish of London for driving us there, and Mann and Pat Bramblette for allowing us to wander freely over their ranch. Our collections were initially sorted by Dr M. R. Cooper (now at the University of Natal), but we found ourselves in disagreement with his taxonomy. We have benefitted enormously from discussions with Dr W. A. Cobban of the United States Geological Survey, Denver, Colorado, who kindly allowed us to quote his unpublished work on Lower Turonian *Inoceramus*. The financial support of the Natural Environment Research Council is gratefully acknowledged. This is a contribution to IGCP project 58 on 'Mid-Cretaceous Events'.

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Typescript received 2 August 1985
Revised typescript received 1 December 1985